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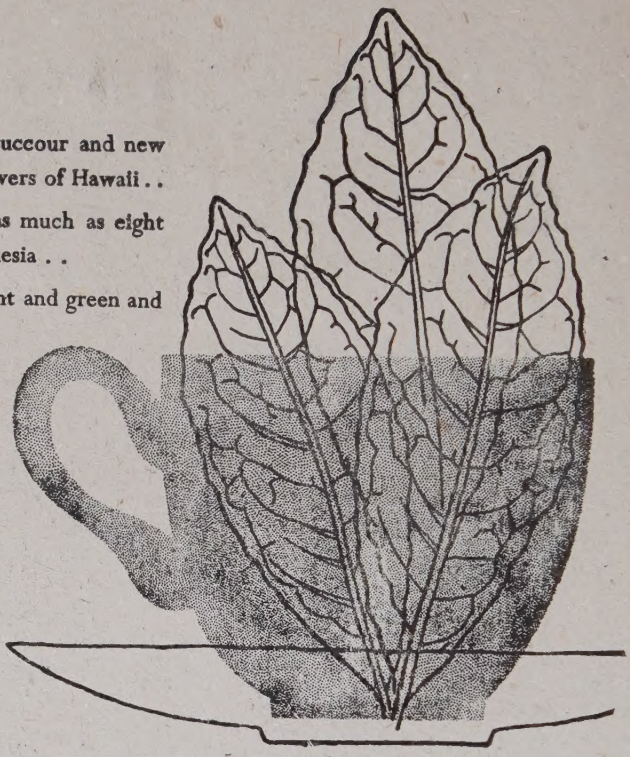

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TROPICAL AGRICULTURIST

AGRICULTURAL JOURNAL OF CEYLON

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Edited by

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Director of Agriculture

CEYLON DEPARTMENT OF AGRICULTURE

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EDITORIAL

The Kantalai Sugar Project

NEARLY A CENTURY AGO, sugar production was an industry of some importance in this country, and in 1859, ten factories operated in the Central, Western and Southern Provinces. During the period, 1845-1859, Ceylon's exports of sugar amounted to 2,170 tons. Today a few hundred acres of cane on the banks the Gin Ganga represent the last relic of this industry.

For nearly a decade, this country has tinkered at the idea of resuscitating its almost defunct sugar industry. The importance of achieving self sufficiency in a commodity the imports of which in 1957 cost the country 99 million rupees needs no emphasis. It has been argued that sugarcane encroaches on the irrigation water allocated to rice. But for the same amount of irrigation water, cane produces nearly three times as much food as rice. Moreover, through its depressant effect on the pests, diseases and weeds, sugarcane would contribute to higher yields of the rice crop that rotates with it.

Data provided by the Sugarcane Research Station, Polonnaruwa, provide a basis on which a sugar industry can be established with complete confidence. The performance of the canes Co 453, Co 527, Co 421, Co 617, Co 449 has been outstanding : the canes mature in 12-14 months. cane yields have been high, the juice purity is of the order of 85-90 per cent., and the estimated recovery of sugar amounts to 9-12 per cent. The Polonnaruwa plots have been estimated to yield 3-4 tons of sugar per acre.

At the low estimate of a per-capita consumption of 35 lb. per year—the United Kingdom consumes 95 lb. per capita per year—the requirements of a population of nine millions aggregate 140,000 tons of sugar. Results obtained by the Department of Agriculture indicate that yields of plant cane and ratoon crops should average 30 tons of millable cane per acre. At a rendement of 10 per cent, the annual harvested acreage needed for immediate self sufficiency does not exceed 47,000 acres. Towards the end of 1956, the Hon'ble the Minister of Agriculture and Food directed the Department of Agriculture to establish under the Kantalai tank, a sugar plantation that provides initially an annual harvest of approximately one tenth this requirement. Kantalai, apart from being near a rail head, has extensive areas of soils suitable for cane. A survey revealed that the soils were generally sandy loams

which would respond to added nitrogen and phosphorus. The composition of the parent rock suggests that sufficient reserves of the other plant nutrients should be available. Geologically the area consists chiefly of acid Khondalite gneisses which weather slowly and develop shallow soils. The topography of the area, however, permits convenient drainage—a point of considerable importance in a crop as sensitive to wet feet as sugarcane.

Under the Department's programme at Kantalai, cane would yield three crops, viz. plant cane and two ratoons, before it is uprooted and is succeeded by a rice season. The first planting of 1,600 acres has already commenced, and plantings of 1,600 acres in April-June will continue in successive years.

The earliest planting of 1,600 acres will, after two ratoons, give way to a rice crop in 1961 ; the land will be back again under cane in 1962. The system of monoculture practised in countries like Hawaii has its attractions, but for various economic and agronomic reasons, rotation with rice should be preferred.

The plantation of 4,800 acres cane (viz. 1,600 acres plant cane, 1,600 acres first ratoon and 1,600 acres second ratoon) and the rice acreage of 1,600 aggregate 6,400 acres. The gross extent of 8,000 acres allocated for the first stage in sugar development at Kantalai allows a margin of 15 per cent. on 6,400 acres for roads, bunds, channels, rock, &c., and 600 acres for nurseries.

The vacuum-pan factory that will crush the first harvest of 1,600 acres of plant cane in 1959 has a minimum crushing capacity of 1,200 tons of cane per day (50 tons per hour), but can be expanded to a capacity of 1,700 tons per day. Climatic conditions in the dry zone permit a crushing season of over 120 days commencing in July. The factory is designed to produce sugar of the quality " plantation white " by the sulphitation process. This quality will meet the requirements of most consumers. Ceylon's consumption of refined sugar is negligible.

The cost of growing a ton of cane at Kantalai is estimated at about Rs. 25. Assuming an expenditure in the factory of Rs. 20 per ton and a 10 per cent. recovery rate, a ton of sugar should cost about Rs. 500. Cane yields are expected to show striking increases in a few years when the Kantalai plantation becomes stabilized, and production costs should then decline. Moreover, by-products would contribute to profits. Nearly 5,000 tons of molasses should become available each year. A great part of this by-product will probably be used in cattle feeds which can contain up to 10 per cent. molasses. The manufacture of power alcohol from molasses can also be a valuable adjunct to the sugar factory.

The extension of the sugar acreage at Kantalai is not restricted by the capacity of the Kantalai tank. Striking potentialities for sugar growing under lift irrigation from the Mahaweli Ganga exist.

STUDIES ON THE NUTRIENT STATUS OF SOME COCONUT SOILS IN CEYLON

1. THE LATERITIC SOILS OF "BANDIRIPPUWA" ESTATE

B. Preliminary Experiments with "Lateritic Loam" and "Lateritic Sand"

By T. B. PALTRIDGE and K. SANTHIRASEGARAM

(Coconut Research Institute, Ceylon)

INTRODUCTION

THIS PAPER is one of a series emanating from the Coconut Research Institute Division of Agronomy, and published under a common title, "Studies on the Nutrient Status of some Coconut Soils in Ceylon." It records data from experiments with the "*Lateritic Loam*" and the "*Lateritic Sand*" on Bandirippuwa Estate. The objectives and the techniques employed are in all respects similar to those described in our previous publication.

These two soils were selected as important derivatives of the "*Lateritic Gravel*", which appears to be the parent material from which both are derived. The "*Lateritic Loam*" is a grey loamy sand, which may be one to four feet deep, overlying a more typical laterite. It appears to be an accumulation of what was originally surface soil on adjacent lateritic ridges. The "*Lateritic Sand*" is confined to the valley floors and to flat open country where there is, or has been, freely moving water. It is a grey-white sand overlying kaolinitic clay at a depth of approximately six feet. There is no apparent stratification, and no hard-pan. The surface sand is loose and friable, but the deeper sands are frequently, compressed and partially cemented.

Samples of those soils were collected from a number of places in different areas, and they were thoroughly mixed to provide uniform material for use in pot experiments. Individual samples included all material above a depth of nine inches, but the coarser vegetable matter (stems, leaves and larger roots) were subsequently removed.

That soil was then used to fill a number of 6 inch polysterene flower pots :— each containing approximately 2,000 gms. (dry weights), and the response to any nutrient was measured in terms of the dry weight of plants grown in every pot. All pots were watered daily, their water content being brought to a constant level (85 per cent. field capacity) by weight.

In order to avoid contamination, the water was filtered, passed through a commercial water softener, distilled and re-distilled before use. The final distillation was in Pyrex glass. The test plants were a perennial pasture grass (*Paspalum commersonii Lam.*) and a legume (*Phaseolus lathyroides* L.).

2. EXPERIMENTAL

A. Experiment 1

(i) **Objective.** To measure the effect of major nutrients (N, P, K, Ca and Mg) and of " X " (a mixture of Cu, Zn, Mn, Fe, B and Mo), on the yield of *Paspalum commersonii* growing on " *Lateritic Loam* ".

(ii) **Design and Procedure.** This was a 2^6 factorial experiment, with only one replicate of each treatment. All nutrients were applied in forms and doses enumerated in Table I.

The *Paspalum* was planted on October 5, 1956, and harvested three times, viz. :—on November 6, and December 18, 1956, and on January 21, 1957 : Additional nutrients were applied as follows :—

TABLE I—*Forms and rates of fertilizer applied in Experiment 1*

Designation	*Chemical*	*Rate of Application/Acre*
K_3 ..	K_2SO_4	3 cwt. ≡ 150 lb. K + 70 lb. S
P_3	$NaH_2PO_4.2H_2O$	3 cwt. ≡ 67 lb. P + 49 lb. Na
N_5	$(NH_4)_2SO_4$	5 cwt. ≡ 118 lb. N + 135 lb. S
Ca_{10}	$CaCO_3$	10 cwt. ≡ 4 cwt. Ca +
$Mg_{1\frac{1}{2}}$	$MgSO_4.7H_2O$	$1\frac{1}{2}$ cwt. ≡ 18 lb. Mg + 22 lb. S
Cu_{14}	$CuSO_4.5H_2O$	14 lb. ≡ 3.6 lb. Cu + 1.7 lb. S
Zn_{14}	$ZnSO_4.7H_2O$	14 lb. ≡ 3.0 lb. Zn + 1.6 lb. S
Mn_{14}	$MnSO_4.4H_2O$	14 lb. ≡ 3.5 lb. Mn + 2.0 lb. S
Fe_{14}	$FeSO_47H_2O$	14 lb. ≡ 2.8 lb. Fe + 1.6 lb. S
B_6	$Na_2B_4O_7.10H_2O$	6 lb. ≡ 1.0 lb. B + 1.0 lb. Na
Mo_1	$(NH_4)_5.Mo_7O_{24}.4H_2O$	1 lb. ≡ 0.53 lb. Mo + 0.716 lb. N

On December 5, 1956—5 cwt./acre $(NH_4)_2\ SO_4$ were applied to all pots with added N Total dose then ≡ 236 lb /acre of N

On December 11, 1956—$1\frac{1}{2}$ cwt./acre of K_2SO_4 were applied to all pots with added K. Total dose then ≡ 225 lb./acre of K

On January 16, 1957—5 cwt./acre $(NH_4)_2SO_4$ were applied to all pots with added N. Total dose then ≡ 344 lb./acre of N.

(iii) **Results.** Magnesium and " X " had no significant, or apparent effect on yields in any harvest, and mean yields for four replicates (Nil, Mg, " X " and MgX) are recorded in Table II.

TABLE II.—*Experiment 1. Showing mean yields for four replicates (nil, Mg. 'X' and MgX), and level of significance for treatments affecting the yield of* Paspalum commersonii *in three successive harvests. n.b. Significance at 5 per cent. not recorded*

Harvest	*Treatment*		*Nil*	*P.*	*N.*	*N.P.*	*Effective Treatment*	*Level of Significance. %*
1		nil	1·01	1·27	1·36	3·57	K.	0·1
	nil	K	1·28	1·35	1·32	5·20	N	1·0
Age 42							KN.	0·1
Days		nil	0·88	1·33	1·39	3·46	Harvest	1·0
	Ca	K	1·47	1·38	1·36	5·13	P. Harvest	0·1
							Ca. Harvest	1·0
2	nil	nil	0·69	0·68	2·16	2·10	P. N. Harvest	0·1
		K	0·84	0·64	3·68	3·89	K. N. Harvest	1·0
Age 74								
Days		nil	1·05	0·87	2·91	2·02		
	Ca	K	1·22	0·77	3·69	2·92		
3	nil	nil	0·40	0·37	0·02	0·00		
		K	0·37	0·36	2·29	2·46		
Age 108								
Days		nil	0·56	0·61	1·51	0·23		
	Ca	K	0·52	0·48	5·75	4·43		

The effect of these four nutrients, and of magnesium, in successive harvests are shown diagrammatically in Fig. 1. Cumulative yields are shown in Fig. 2.

The data show that N. P. K. and Ca all had a very big effect on yield. They were most effective when used in combination, and there were a number of interactions between " nutrients " and " harvest ", which devolved from a hanging pattern of responses in successive harvests. Those responses may be summarized as follows :—

1st Harvest. In the first harvest there was no significant response to N. alone ; P. and K. alone were responsible for small increases (increments of 26 per cent.), and there were very big responses to N.P. (increment of 254 per cent.). and to N.P.K. (increment of 414 per cent.), Neither Ca. nor Mg. had any significant effect on yield.

2nd Harvest. In the second harvest, P. or K. alone had no significant effect on yield, but there was a big response to N. (increment of 213 per cent.), and to N.K. (increment of 432 per cent.) ; N.P. gave an increment of 204 per cent. (c.f. 213 per cent. for N. alone) ; N.P.K an increment of 475 per cent. (c.f. 342 per cent. for N.K. alone).

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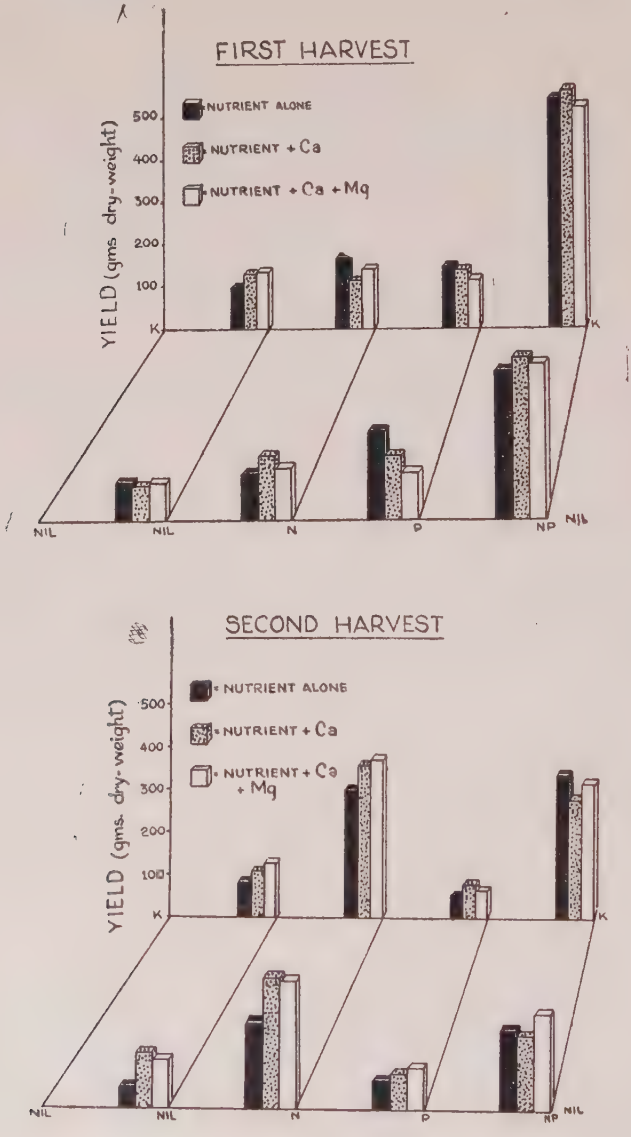
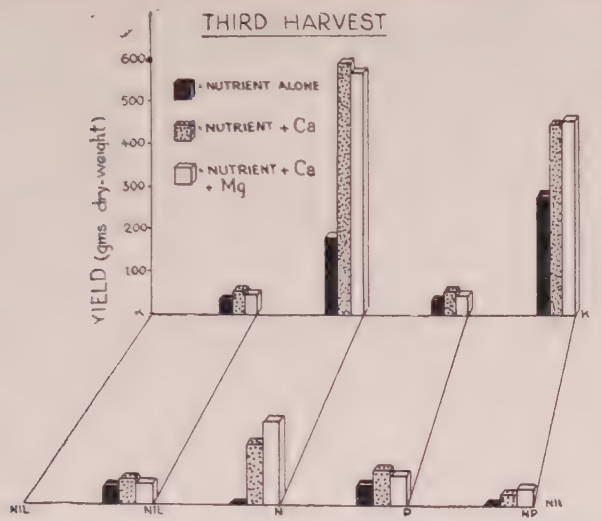
There was no significant improvement from the addition of Ca, but there was a small negative interaction between Ca. and P.

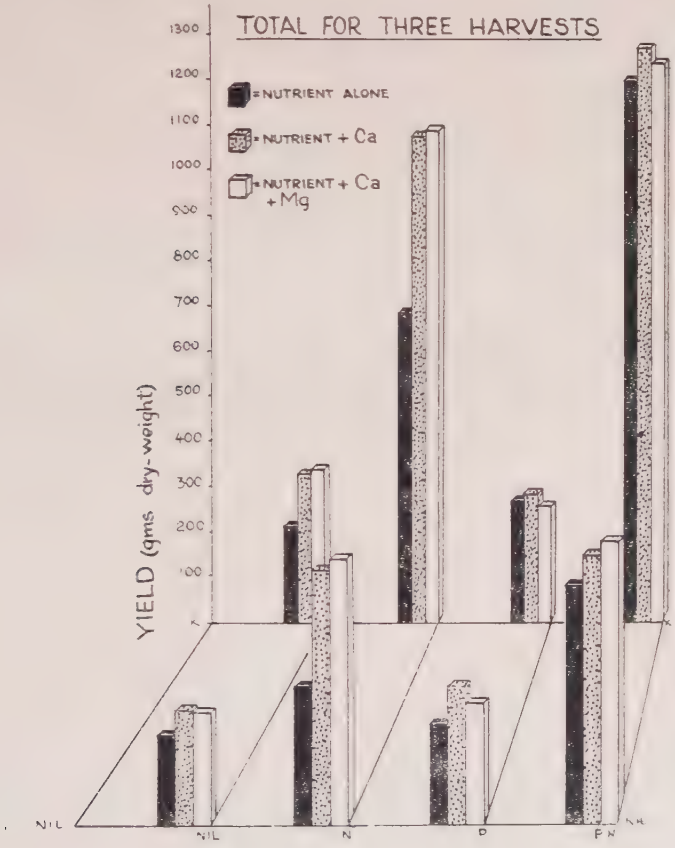
3rd Harvest. In the third harvest P. and K. alone or in combination, had no effect on yield. In presence of N. alone, three out of four plants died, and with N. P. alone, all plants died. N. K. gave an increment of 465 per cent., and N. P. K. an increment of 508 per cent.

Fig. 1.—*Experiment 1. Diagram showing mean yields for two replicates of all treatments in three successive harvests of* Paspalum commersonii.





(Below) Fig. 2.—*Experiment 1. Diagram showing Cumulative yields from three harvests of* Paspalum commersonii



In this harvest Ca. also had a very big effect, and N.Ca., N.K.Ca., and N.P.K.Ca., gave increments of 273 per cent, 1,321 per cent and 994 per cent., respectively.

B. Experiment 2

(i) **Objective.** To measure the effect of major nutrients (N. P. K. Ca. and Mg), and of " X " (a mixture of Cu, Zn, Mn, Fe, B and Mo), on the yield of *Paspalum commersonii* growing on " *Lateritic Sand* ".

(ii) **Design and Procedure.** The design of this experiment was identical with that of *Experiment 1* and all nutrients were applied in forms and doses enumerated in Table 1. The experiment was planted on January 22, 1957, and harvested four times, viz. :—on March 11, May 6, June 7 and July 8, 1957. Additional nutrients were applied as follows :—

On March 5, 1957— 2.5 cwt./acre $(NH_4)_2\ SO_4$ were applied to all pots with added N. Total dose then ≡ 177 lb./acre of N.

On April 16, 1957— 4 cwt./acre NH_4NO_3 were applied to all pots with added N. Total dose then ≡ 335 lb./acre of N.

On May 10, 1957— 3 cwt./acre K_2SO_4 ; 3 cwt. Na $H_2PO_4\ 2H_2O$; and 17.5 lb /acre " X " were applied to all pots with added K. P. and X, respectively. Total dose then ≡

300 lb./acre of K.
134 lb./acre of P.
5.4 lb./acre of Cu.
5·2 lb./acre of Mn.
1.5 lb./acre of B.
0.8 lb./acre of Mo.

On June 7, 1957— 2 cwt./acre NH_4NO_3 were applied to all pots with added N. Total doe then ≡ 414 lb./acre of N.

(iii) **Results.** Cumulative yields from the four harvests, and from all treatments are recorded in Table III and in Figs. 3 and 4.

TABLE III.—*Experiment 2. Showing cumulative yields, and level of significance for all treatments affecting the yield of* Paspalum conmersonii. *n.b. Significance at 5 per cent. recorded.*

Treatment				*Nil*	*Mg.*	*X*	*MgX*	*Effective Treatments and Level of Significance*	
			nil	2·24	2·94	3·75	2·86	K. (.1)	K.P.N. —
	nil		K.	2·53	2·86	2·59	3·29	P. —	K.P.Ca. (1.0)
								N. (.1)	K.P.H. —
nil								Ca. (.1)	K.N.Ca. (.1)
								Harv. (.1)	K.N.H. (.1)
		P.	nil	3·17	3·73	3·84	3·73	K.P. —	K.Ca. H. (.1)
			K.	2·72	2·80	3·27	2·92	K. N. (.I)	P.N.Ca. (1.0)
								K.Ca. (.1)	P.N.H. (1.0)
nil								K.H. (.1)	P.Ca. H. (1.0)
								P.N. —	N.Ca.H. (.1)
			nil	6·02	6·02	6·99	9·01	P.Ca. —	K.P.N.Ca. —
		nil	K.	7·46	12·12	9·84	16·48	P.H. (1.0)	K.P.N.H. —
								N.Ca. (.1)	K.P.Ca.H.(1.0)
	N.							N.H. (.1)	K.N.Ca.H. (.1)
								Ca. H.(.1)	K.P.Ca.H. (.1)
			nil	3·72	3·78	8·44	7·70		P.N.Ca. H. (.1)
		P.	K.	6·84	5·64	12·15	9·33		
			nil	2·72	4·31	3·63	3·86		
		nil	K.	4·40	4·00	3·68	3·61		
	nil								
			nil	4·14	5·21	4·38	4·41		
		P.	K.	4·59	2·25	2·90	3·93		
Ca.									
			nil	9·99	11·38	7·73	11·58		
		nil	K.	19·45	23·83	23·06	20·74		
	N.								
			nil	7·57	8·34	6·95	8·32		
		P.	K.	30·03	29·51	32·27	33·22		

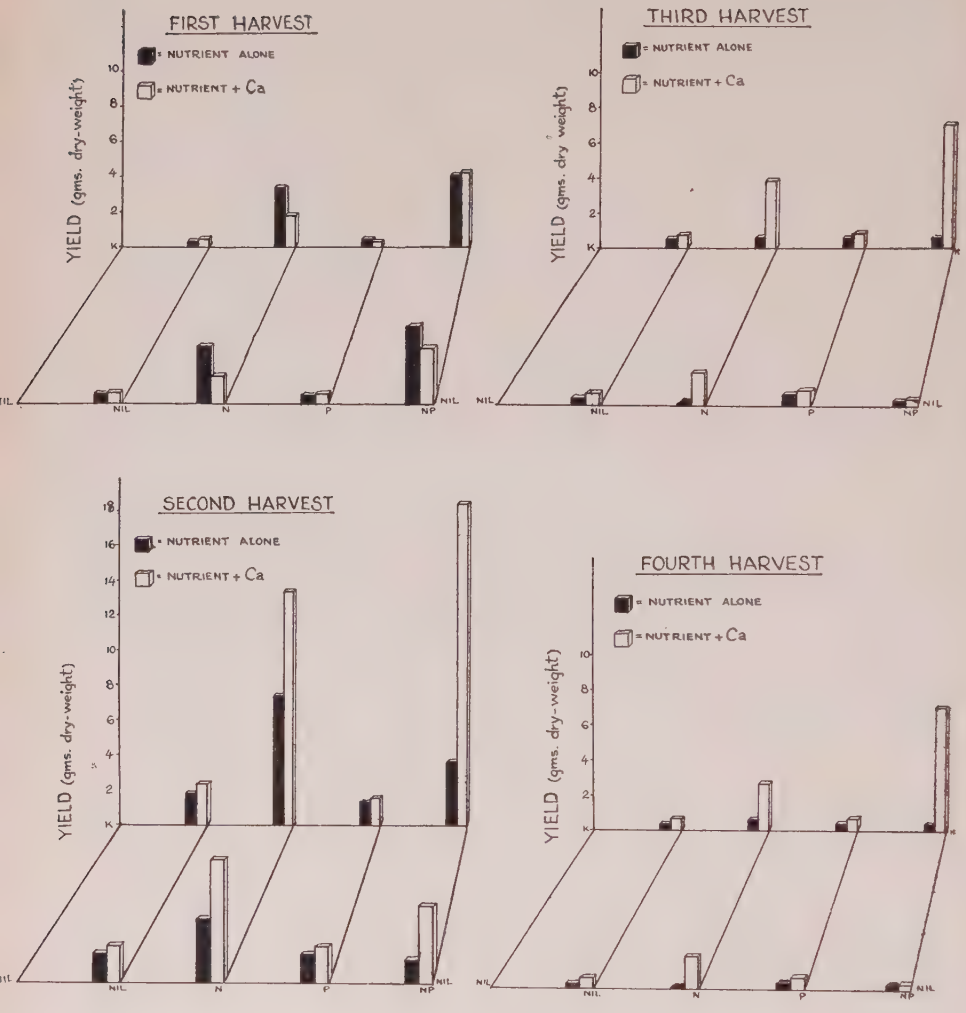


Fig. 3.—*Experiment 2. Diagram showing mean yields for two replicates of all effective treatments, in four successively harvests of* **Paspalum** commersonii.

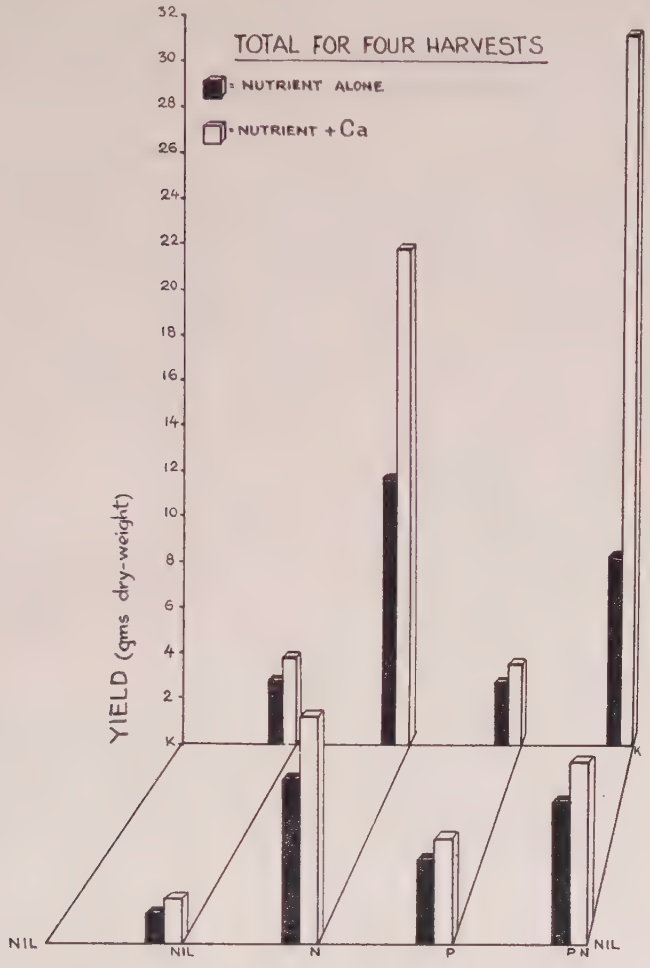


Fig. 4.—*Experiment 2. Diagram showing cumulative yields from four harvest of* Paspalum commersonii.

The data show that there was no significant response to Mg. in any harvest. In the first harvest there was a significant response to X (alone and in combination with N. and K.) which was consistent in four treatments, viz. :—

Treatment	*Effect of X*	*Level of Significance*
X. (alone) ..	+29% ..	1%
K. X. ..	+47% ..	5%
N.X. ..	+25% ..	1%
K.N.X. ..	+52% ..	5%

However, there was no effect from X in subsequent harvests and the data from four replicates (nil, Mg, X and MgX.) were therefore combined as a 2^4 factorial experiment with four replicates and mean yields for each harvest are recorded in Table IV.

TABLE IV.—*Experiment 2. Showing mean yields for four replicates (nil, Mg. × and Mg ×), and level of significance for all treatment affecting the yield of* Paspalum commersonii *in four successive harvests. n.b. Significance at 5 per cent. not recorded*

Harvest	*Treatment*		*Nil*	*N.*	*P.*	*N.P.*	*Effective Treatments and Level of Significance. %*
1	nil	nil	0·45	3·17	0·49	4·42	P. (0·1) P.N. (0·1)
		K.	0·47	3·54	0·40	4·26	N. (0·1) N.Ca. (0·1)
Age 48							Ca. (1·0)
Days		nil	0·41	1·55	0·54	3·30	
	Ca.	K.	0·56	1·86	0·39	4·24	
2		nil	1·67	3·82	1·89	1·47	K. (0·1) K.N. (0·1) K.N.Ca. (0·1)
	nil	K.	1·69	7·30	1·87	3·44	N. (0·1) K.Ca. (0·1) P.N.Ca. (1·0)
Age 104							Ca. (0·1) N.Ca. (0·1)
Days		nil	2·10	6·91	2·28	4·39	
	Ca.	K.	2·32	13·38	1·96	18·43	
3		nil	0·46	0·01	0·67	0·01	K. (0·1) K.P. (1·0) K.P.N. (0·1)
	nil	K.	0·39	0·56	0·40	0·39	N. (0·1) K.N. (0·1) K.P.Ca. (0·1)
Age 136							Ca. (0·1) K.Ca. (0·1) K.N.Ca. (0·1)
Days		nil	0·54	1·54	0·75	0·11	N.Ca. (0·1)
	Ca.	K.	0·58	3·70	0·57	6·74	
4		nil	0·35	0·00	0·56	0·00	K. (0·1) K.N. (0·1) K.N.Ca. (0·1)
	nil	K.	0·26	0·07	0·26	0·39	Ca. (0·1) K.Ca. (0·1)
Age 167							N.Ca. (0·1)
Days		nil	0·58	0·18	0·96	0·00	
	Ca.	K.	0·53	2·82	0·50	1·86	

That data may be summarized as follows :—

1st Harvest. In the first harvest, P. and K. alone or in combination, had no effect on yield, but N. and N.K. gave increments of 602 per cent. and 687 per cent., respectively. N.P. and N.P.K. gave increments of 882 and 847 per cent., respectively.

Calcium was responsible for some depression in yield, and corresponding increments were :—N.Ca. 244 ; N.K.Ca. 313 ; N.P.Ca. 611, and N.P.K.Ca. 842 per cent. Only the N.P.K.Ca. treatment gave a yield comparable with that in absence of Ca.

2nd Harvest. In the second harvest, K. and P. alone or in combination, had no effect on yield ; N. and N.K. gave increments of 128 and 337 per cent., respectively, but in presence of P. they were reduced to ' nil ' (N.P.) and 106 per cent. (N.P.K.).

Calcium alone, was responsible for some increase in yield (increment of 26 per cent.), and there was a progressive improvement, with increments of 314 per cent. (N. Ca.), 701 per cent. (N.K.Ca.), and 1,004 per cent. (N. P. K. Ca.). Any adverse effect from P. was restricted to one treatment (N.P.Ca.) :—increment of 163 per cent. (c.f.314 per cent. for N.Ca.).

3rd Harvest. In the third harvest, N.P. and K. all had only a very small effect on yield ; and it is a point of some importance that in absence of K. three out of the four plants in both N., and N. P. treatments died.

Calcium alone, gave a small increase in yield (increment of 17 per cent.) and in presence of Ca. there was again progressive improvement, with increments of 235 per cent. (N.Ca.), 704 per cent. (N.K.Ca.), and 1,387 per cent. (N.P.K.Ca.). Here again, P. in absence of K. was responsible for some depression in yield.

4th Harvest. In the fourth harvest, P. and K. alone, had very little effect on yield, and in the absence of K., all plants receiving N. and N.P. died. K.N. caused an appreciable decrease in yield (decrement of 80 per-cent.) ; K.P.N. had no significant effect.

Calcium alone, and in the presence of K., gave increments of 66 and 51 per cent. ; P.Ca. an increment of 174 per cent. In the Ca.N. treatments three out of four plants died, and with N.P.Ca. all plants died. N.K.Ca. gave an increment of 707 per cent., and N.P.K.Ca. a lesser increment of 431 per cent.

C. Discussion on Experiments 1 and 2

(i) **Interpretation of Results.** The data from these two experiments show that both " *Lateritic Loam* " and " *Lateritic Sand* " are deficient in N.P.K. and Ca. They also show that there was a changing pattern of responses in successive harvests, with increasingly acute deficiencies of N.K. and Ca., but with some apparent increase in the supply of available P.

These data do not present a clear picture of the extent (i.e. the full effect) of naturally occurring deficiencies, but the amount of growth in absence of any one nutrient can be computed as a *relative yield,* i.e. as a proportion of that when all nutrients were present, and available, in adequate supply, viz :—

$$\text{Relative Yield} = \frac{X}{A} \times 100$$

Where ' A ' = yield with all nutrients in optimal supply, and ' X ' = yield in absence of one, specified nutrient.

A *relative yield* would not be valid if there was any shortage in the supply or availability of nutrients in the complete fertilizer (A). Therefore in these experiments, if there was a big response to any nutrient, if there were deficiency symptoms, or if there was any other reason to suspect that the original dosage of any nutrient was sub-optimal; then more of that nutrient was added to the appropriate pots. That procedure carried with it some risk of over-dosage, but in that event—i.e. if there were adverse effects from overdosage, then *relative yields* would exceed 100 per cent., and appropriate adjustments could be made.

In order to obtain some measure of reliability, the data from a number of replicates (i.e. corresponding values for all treatments that had no significant effect on yield) were separately computed. *Mean Relative Yields*, and standard deviations, were then calculated from those individual values. See Table V.

TABLE V.—*Showing calculation of mean relative yields and standard deviations for the third harvest of Experiment 1.*

Replicate	*YIELD IN GMS.*		*Relative Yield* (-*N*)	*Replicate*	*YIELD IN GMS.*		*Relative Yield* (-*P*)
	N.P.K.Ca.	*P.K.Ca.*			*N.P.K.Ca.*	*N.K.Ca.*	
1 (nil)	4·78	0·64	13	1 (nil)	4·78	5·57	117
2 (Mg)	4·03	0·33	8	2 (Mg)	4·03	6·31	132
3 (X)	4·13	0·51	12	3 (X)	4·13	5·79	140
4 (MgX)	4·78	0·44	9	4 (MgX)	4·78	5·35	112
Mean			10	Mean			125
s.d.			+ 1·2 —				+6.7

Replicate	*YIELD IN GMS.*		*Relative Yield* (-*K*)	*Replicate*	*YIELD IN GMS*		*Relative Yield* (-*Ca*)
	N.P.K.Ca.	*N.P.Ca.*			*N.P.K.Ca.*	*N.P.K.*	
1 (nil)	4·78	0·34	7	1 (nil)	4·78	3·21	46
2 (Mg)	4·03	0·04	1	2 (Mg)	4·03	3·07	76
3 (X)	4·13	0·35	8	3 (X)	4·13	2·92	71
4 (MgX)	4·78	0·21	4	4 (MgX)	4·78	1·65	35
Mean			5	Mean			57
s.d.			+1·6 —	s.d.			+9·8 —

(ii) **Relative yields for 'Lateritic Loam'.** Mean relative yields for *Experiment 1*, are shown diagrammatically in Figs. 5 and 6.

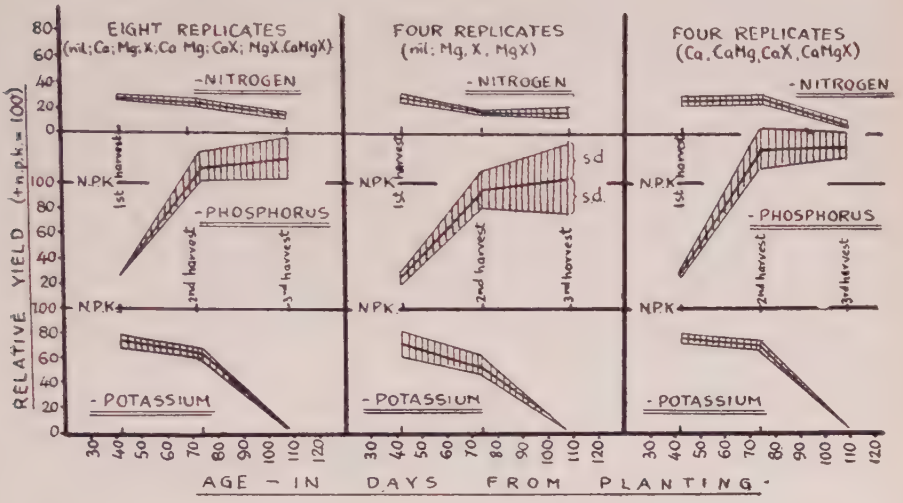


Fig. 5.—*Experiment 1. Diagram showing mean relative yields* ($\pm$ *standard deviation*) *for* ' *no phosphorus* ', ' *no nitrogen* ' *and* ' *no potassium* ', *as calculated from 3 sets of replicates.* (See Text).

In Fig. 5 only the effect of '–N', '–P' and '–K' are recorded but each has been calculated from 3 sets of data (i.e. using different replicates). The pattern of relative yields for '–N' and '–K' is essentially the same in all three diagrams, but there are some differences in the magnitude of relative yields for '–P':— they can be interpreted as follows:—

(a) **No Phosphorus.** In all three diagrams there was at first an acute deficiency of P. (e.g. where Ca. had been applied relative yields for the first harvest did not exceed a mean value of $26 \pm 3 \cdot 1$), but in subsequent harvests—still without any application of phosphorus—relative yields rose steadily to equal, or exceed, that of plants receiving all three nutricients (N.P.K.).

A relative yield which is significantly greater than 100 is possible only if the particular nutrient is having an adverse effect on plant growth:—any toxic compound, for instance, would have that effect.

Too much of any nutrient could have the same effect, but only if all other nutrients were present, and available, in sufficient quantity. Under any other circumstances:—e.g. with incipient deficiency of N.K. or Ca.,—a second limiting factor would intrude, and relative yields could not exceed 100. For example, in this experiment and in absence of Ca. (calcium then being a second limiting factor) relative yields for '–P' did not exceed 100.

The data therefore show that in the second and third harvests of this experiment, the natural supply of available P. was near optimal, and application of 3 cwt./acre $NaH_2PO_42H_2O$ caused some depression in yield.

In all other respects this pattern of relative yields was essentially similar to that recorded from similar experiments with the '*Lateritic Gravel*' (see C.R.I. Bulletin 11), and subject to the same interpretation, viz :—'It must be assumed that available phosphate, which was originally in short supply, had increased; possibly as a result of chemical or biological changes in the soil'.

Finally in this experiment, any effect from excess P. on the complete fertilizer (N.P.K.Ca.) would be reflected in relative yields for '–N', '–K' and '–Ca.'. Therefore in the 2nd and 3rd harvests, relative yields for N, K and Ca. were re-calculated, on a basis of 100 for N.K.Ca. That data was used in compiling Fig. 6.

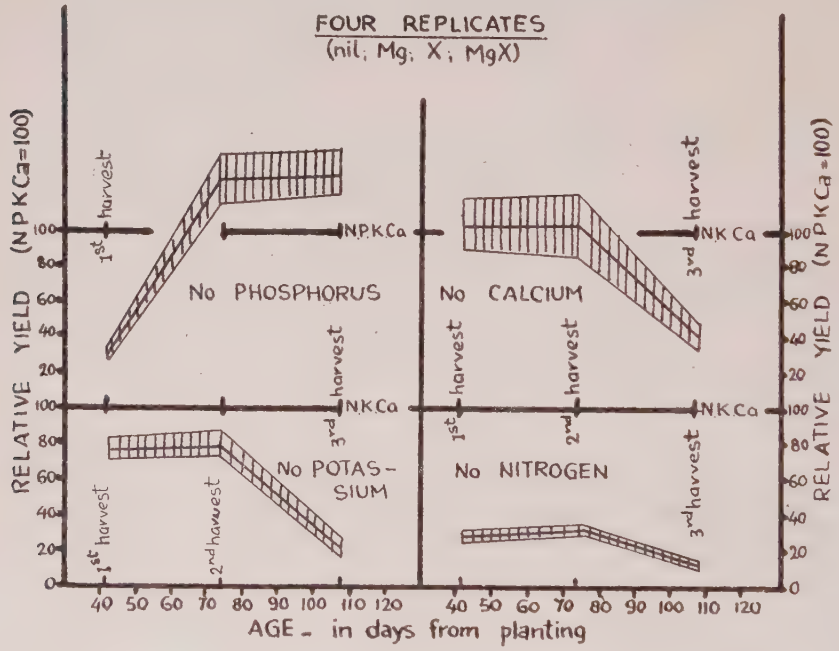


Fig. 6.– *Experiment 1. Diagram showing mean relative yields (± standard deviation), and progressive effects from absence of N. P. K. and Ca, in the 'Lateritic Loam.'*

(b) **No Nitrogen.** Nitrogen was at all times an important limiting factor in plant growth, and relative yields decreased from an initial value of $26 \pm 3 \cdot 1$ to a final value of $10 \pm 1 \cdot 2$. In other words, the experiment has shown that

without some application of nitrogen, no amount of fertilizers will give yields exceeding 1·4 to 1·8 the potential level of production on this soil.

(c) **No Potassium.** In the absence of potassium relative yields decreased steadily from an initial value of 76±3·4 to final values of 20±5·9. They did not tend towards an asymptote, and all K_0 plants eventually died. As with the '*Lateritic Gravel*', these data suggest that there had been a gradual fixation of available K.

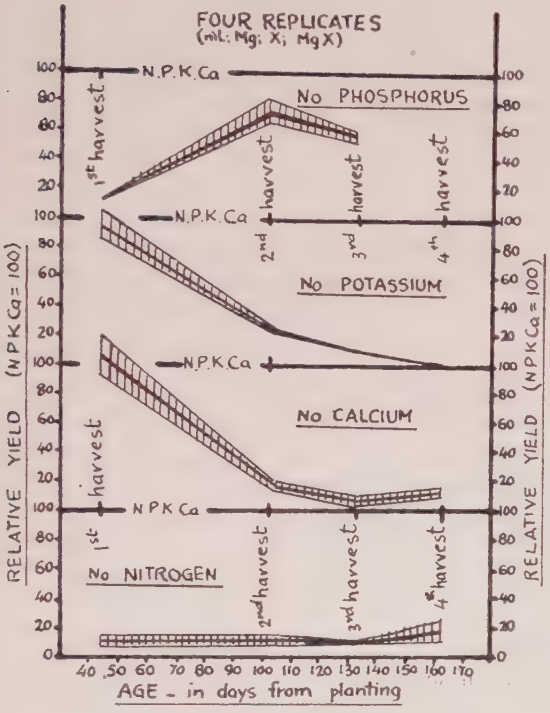


Fig. 7.—*Experiment 2. Diagram showing mean relative yields (± standard deviation), and progressive effects, from absence, of N.P.K. and Ca, in 'Lateritic Sand'*

d) **No Calcium.** In the absence of calcium relatively yields decreased steadily from a mean value of 104±13·4 in the first harvest, and 102±17·1 in the second harvest, to 40±7·2 in the third harvest. Initially, i.e. prior to the first harvest, there was visual evidence of some depression from Ca., but that effect was short-lived.

(iii) **Relative Yields for the 'Lateritic Sand'.** In *Experiment 2* relative yields were calculated on a basis of N.P.K.Ca.=100; and the data for each of the first three harvests are shown diagrammatically in Fig. 7. In the fourth harvest there was again some complication from excess P and relative yields for '–N', '–K' and '–Ca.' were calculated on a basis of N.K.Ca.=100.

(*a*) **No Phosphorus.** In absence of P., relative yields rose sharply from 11±1·2 in the first harvest, to an over-all mean value of 64 ±5·8 for the second and third harvests. In the fourth harvest there was a very big increase to 151±25·4.

As in *Experiment* 1, a relative yield exceeding 100 could not be reconciled with any deficiency of N.K. or Ca. in the complete fertilizer, and the very high

values—which were recorded in all four replicates of the fourth harvest—must be interpreted as showing excess P. in the complete fertilizer (N.P.K.Ca.). Moreover in this experiment that effect would be aggravated by the addition of more $NaH_2PO_4 2H_2O$ on 10th May. Those artificially inflated values were not incorporated in Fig. 7.

For that harvest (No. 4), mean relative yields for '–N', '–K' and '–Ca' were re-calculated, on a basis of 100 for N.K.Ca. and those values were used in completing Fig. 7.

(*b*) **No Nitrogen.** In absence of N., and in the first three harvests, relative yields were consistently low (over-all mean value of $10 \pm 1{\cdot}2$). In the fourth harvest they were some what higher (18 ± 8), but not significantly greater than the over-all mean for the first three harvests. Prior to the first harvest there was visual evidence of still better growth, but that effect was very short lived and it did not affect yields for the first harvest.

(*c*) **No Potassium.** In absence of K. and in the first three harvests, relative yields decreased steadily from an initial value of $95 \pm 9{\cdot}8$ (first harvest), through $24 \pm 1{\cdot}0$ (second harvest) to $9 \pm 1{\cdot}3$ (third harvest). The decline however, was some what less rapid than in other soils and there was a reversed inflection suggesting some loss of any capacity for K- fixation in this soil. In the fourth harvest, all K_0 plants were dead.

(*d*) **No Calcium.** In absence of Ca., relative yields declined rapidly from an initial value of $105 \pm 14{\cdot}5$ for the first harvest to $18 \pm 3{\cdot}0$ and $6 \pm 3{\cdot}6$ in the second and third harvests respectively. In the fourth harvest, two out of the four Ca_0 plants were dead, and the mean relative yield (c.f. N. K. Ca. =100) was 14 ± 2.

D. Experiment 3

(i) Objective. To measure the effect of sulphur on the yield of two species growing on '*Lateritic Loam*'.

(ii) Design and Procedure. This was a simple comparison of two treatments 'nil' and 'sulphur', using two species (*Paspalum commersonii* and *Phaseolus lathyroides*). There were ten formulations comprising five mixtures containing sulphur (i.e. K_2SO_4 ; $(NH_4)_2SO_4$; $MgSO_4$; $CaSO_4$; H_2SO_4 ;and S_4) and five with no sulphur (i.e. KCl ; NH_4NO_3 ; $MgCl_2$; $CaCO_3$; HCl ; and nil). All formulations contained the same amounts of N, Mg and Ca, and all pots were given a basal dressing of K. (5 cwt./acre KCl) and P. (3 cwt./acre $NaH_2PO_4 \cdot 2H_2O$). The basic treatment was S_4.(0·175 gms./pot = 123 lb./acre of S.). The *Paspalum* was planted on 15th and the *Phaseolus* on 28th May, 1957. Both species were harvested once, viz :—the *Paspalum* on July 17, the *Phaseolus* on July 23, 1957.

(iii) Results. Individual yields are recorded in Table VI.

TABLE VI—*Experiment 3. Showing individual and mean yields for two treatments.*

Species	*Treatment*	$(NH_4)_2SO_4$ NH_4NO_3	$MgSO_4$ $MgCl_2$	$CaSO_4$ $CaCO_3$	H_2SO_4 HCl	S_4 *Nil*	*Total*
Paspalum	nil	3·45	1·45	0·51	2·14	1·68	9·23
	S	2·02	2·34	2·17	1·85	1·41	9·79
Phaseolus	nil	0·98	0·57	1·21	1·26	1·51	5·53
	S	0·50	1·13	0·62	1·06	1·14	4·45
Mean	nil	2·21	1·01	0·86	1·70	1·59	7·37
	S	1·26	1·73	1·39	1·45	1·27	7·10

Sulphur had no effect on the yield of either species.

E. Experiment 4

(i) **Objective.**—To measure the effect of sulphur on the yield of two species growing on '*Lateritic Sand*'.

(ii) **Design and Procedure.** The design of this experiment was identical with that for *Experiment* 3, and the same two species (*Paspalum commersonii* and *Phaseolus lathyroides*) were grown. The *Paspalum* was planted on 15th and the *Phaseolus on* 28th May, 1957. They were harvested once, on 17th and 28th July, 1957, respectively.

In the original design for *Experiments 3 and 4* one more comparison viz :—K_2SO_4 *vs* KCl was included. However in both experiments, and in similar experiments with other soils, the K_2SO_4 treatment was—in all cases—outstanding (e.g. in these two experiments, yields of 10.99 and 10.11 were recorded), no explanation is available, but in view of that general result, the K_2SO_4, and KCl yields were not included in the data for these two experiments.

(iii) **Results.** Individual yields are recorded in Table VII.

TABLE VII—*Experiment 4. Showing individual and mean yields for two treatments*

Species	*Treatment*	$(NH_4)_2SO_4$ NH_4NO_3	$MgSO_4$ $MgCl_2$	$CaSO_4$ $CaCO_3$	H_2SO_4 HCl	S_4 Nil	*Total*
Paspalum	nil	0·78	2·15	0·77	0·96	0·27	4·93
	S	4·15	3·41	3·42	4·11	5·38	20·83
Phaseolus	nil	0·55	0·33	1·02	0·97	0·56	3·43
	S	0·72	0·72	0·94	0·85	0·84	4·07

In this experiment, *Phaseolus lathyroides* made very unhealthy growth, and all plants were infected by virus, and by a species of fungus which grew on the leaves :—There were no significant differences between treatments. Plants of *Paspalum commersonii* grew well, and they showed a marked response to sulphur :—which gave a mean increment of 620 per cent.

The data therefore show that plants growing on the "*Lateritic Sand*" would suffer from a deficiency of sulphur. In "*Lateritic Loam*" (and in "*Lateritic Gravel*") there was no evidence of sulphur deficiency.

F. Experiment 5

(i) **Objective.** To measure any effect from increasing dosage of boron and of calcium on the yield of *Phaseolus lathyroides* growing on two soils ("*Lateritic Loam*" and "*Lateritic Sand*").

(ii) **Design and Procedure.** This was a $4 \times 3 \times 2$ factorial experiment with one replicate of each treatment. All pots were given a basal dressing of N, P, K, Mg, Fe, Cu, Mn, Zn, and Mo. The N. was applied as NH_4NO_3, (3 cwt./acre) ; K. as K_2SO_4, ($4\frac{1}{2}$ cwt./acre) ; all others in forms and doses enumerated in Table I. There were three levels of calcium :—0, 10 and 20 cwt./acre $CaCO_3$, and four levels of boron :—0, 3, 6 and 9 lb./acre of $Na_2B_4O_7.10H_2O$.

For this experiment, and in order to avoid boron contamination (i.e., from "Pyrex glassware"), all water was finally distilled in chromiumplated copper apparatus.

The *Phaseolus* was planted on 12th May, 1957, and harvested twice, viz. :—on June 28, and July 23, 1957. All plants were grown from seed, and all seedlings in excess of two, uniform plants per pot were removed as they appeared.

On 10th June, 1957, that number was reduced to one plant per pot, and the "thinnings" were weighed, to give some additional data.

(iii) **Results.** Individual yields for "thinnings", and for two harvests are recorded in Talbe VIII.

TABLE VIII—*Experiment 5. Showing individual yields, and level of Significance for all treatments affecting the yield of* Phaseolus lathyroides

Soil	*Harvest*	*Treatment*	B_0	B_3	B_6	B_9	*Effective Treatment*	*Level of Significance*
LOAM	Thinnings Age 29 Days	Ca_0	0·14	0·23	0·18	0·16	B. (—)	5·0
		Ca_{10}	0·14	0·22	0·14	0·14	Harvest	0·1
		Ca_{20}	0·14	0·16	0·20	0·14	Soil	5·0
							B. Harv.	5·0
	(1) Age 47 Days	Ca_0	3·43	2·52	1·78	2·50	Har. Soil	0·1
		Ca_{10}	2·78	2·44	1·36	2·32	B.Har.Soil	5·0
		Ca_{20}	2·98	2·45	2·62	2·25		
	(2) Age 72 Days	Ca_0	0·91	1·06	1·19	0·85		
		Ca_{10}	1·19	1·21	1·25	1·16		
		Ca_{20}	1·09	1·20	0·73	0·95		
SAND	Thinnings Age 29 Days	Ca_0	0·03	0·07	0·04	0·03		
		Ca_{10}	0·04	0·05	0·04	0·03		
		Ca_{20}	0·02	0·06	0·07	0·08		
	(1) Age 47 Days	Ca_0	1·05	1·10	1·09	0·45		
		Ca_{10}	1·34	0·83	1·44	0·55		
		Ca_{20}	0·70	1·22	0·92	0·35		
	(2) Age 72 Days	Ca_0	1·29	0·98	0·69	1·06		
		Ca_{10}	1·42	1·08	1·09	0·92		
		Ca_{20}	1·49	1·45	1·19	1·23		
	MEAN		1·12	1·02	0·89	0·84		

In both of these soils boron was responsible for some depression in yield. That effect was small, but progressive (decrements of 10, 20 and 25 per cent. for B_3, B_6 and B_9, respectively). It was significant at the five per cent level

G. Experiment 6

(i) **Objective.** To measure the effect of minor nutrients on the yield of *Paspalum commersonii*, grown on "*Lateritic Sand*".

(ii) **Design and Procedure.** This was a 2^5 factorial experiment using four nutrients (Fe, Cu, Mn and Zn), and two replicates of each treatment. All pots

were given a basal dressing of N, P, K, Ca, Mg and B. Calcium (10 cwt./acre $CaCO_3$) was mixed with the upper $1\frac{1}{2}$ inches of soil ; all other nutrients were applied in solution.

Nitrogen was applied as NH_4NO_3 (3 cwt./acre), K as K_2SO_4 ($4\frac{1}{2}$ cwt./acre) ; all other nutrients in forms and doses enumerated in Table I. The experiment was planted on 12th May, 1957, and harvested twice, i.e. on 26th June, and 17th July, 1957. All plants were grown from seed, and seedlings in excess of two uniform plants per pot were removed as they appeared. On 10th June, this number was reduced to one plant per pot, and the " thinnings ", were weighed to provide some additional data.

(iii) **Results.** Total yields for two replicates are recorded in Table IX.

TABLE IX—*Experiment 6. Showing total yields from two replicates, and level of significance for all treatments affecting the yield of* Paspalum commersonii. *n.b. Significance at 5 per cent. not recorded.*

Harvest	*Treatment*		*Nil*	*Mn.*	*Zn.*	*Mn. Zn.*	*Effective Treatment*	*Level of Significance per cent.*
Thinnings	nil	nil	0·23	0·25	0·25	0·23	Cu.	0·1
		Cu.	0·22	0·26	0·13	0·25	Harvest	0·1
Age 29 Days	Fe.	nil	0·28	0·24	0·21	0·27	Cu. Fe.	1·0
		Cu.	0·23	0·27	0·24	0·19	Cu. Harv.	1·0
(1)	nil	nil	3·49	3·67	4·08	4·27		
		Cu.	3·99	3·95	3·51	3·42		
Age 45 Days	Fe.	nil	3·94	3·95	3·74	3·26		
		Cu.	4·06	5·05	5·40	4·56		
(2)	nil	nil	3·10	3·46	3·83	3·29		
		Cu.	3·69	4·70	3·88	4·46		
Age 66 Days	Fe.	nil	3·36	2·55	3·42	3·00		
		Cu.	4·09	5·22	4·48	5·88		

The data showed that there was no effect from zinc, or manganese, in any harvest ; but in the first harvest copper and iron—together, were responsible for some increase in yield (mean increment of 35 per cent.). In the second harvest, copper alone gave a mean increment of 45 per cent., and there was no effect from iron. In " thinnings " there was no effect from any of the minor elements.

The data therefore show that in the early stages of growth (i.e. at ages of 45 and 66 days) there was a small but significant deficiency of copper and

a transitory effect from iron. In *Experiment 1*, those effects were shortlived, and it is unlikely that any addition of trace elements would be economically worth-while at the present time.

However, the supply of available copper and of iron was barely sufficient, and might, in time, become more acute. Some further experiments with high-yielding crops, or pasture, are therefore desirable.

3. SUMMARY AND CONCLUSIONS

1. The data from six experiments with "*Lateritic Loam*" and "*Lateritic Sand*" have shown that these two soils are both deficient in nitrogen, potassium, and calcium. Both have shown an initial deficiency of phosphorus and a common tendency towards increasing supply of naturally occurring available phosphorus in later harvests of *Paspalum commersonii*. Only the "*Lateritic Sand*" has shown a deficiency of sulphur.

2. In the "*Lateritic Sand*" there was a small response to copper and some suggestion of an "incipient deficiency" of iron during the early stages of growth. However, that effect was short-lived, and application of trace elements is not likely to be economically worth-while at present. Some further experiments with high-yielding crops, or pasture, are desirable.

3. The data from these experiments, and from similar experiments with the "*Lateritic Gravel*" on Bandirippuwa Estate, have shown that the three soils are essentially similar in their nutrient status. This similarity was evident from a changing pattern of *relative yields*, which was common to all three soils.

4. The pattern of responses in "*Lateritic Gravel*" "*Lateritic Loam,*" and "*Lateritic Sand*"—in that order—showed some important differences in the magnitude of relative yields, together with a progressive deficiency of calcium. There was also some suggestion of a *decreasing capacity* for K.-fixation. All three soils showed an acute deficiency of nitrogen :—which is not a mineral nutrient.

5. In the "*Lateritic Gravel*", relative yields for the P_0 treatments rose to a maximum value of 70 : calcium deficiency was not apparent until the fourth harvest (i.e. after 150 days) : and relative yields for the K_0 treatments fell sharply to zero at 150 days.

6. In "*Lateritic Loam*" relative yields for the P_0 treatments rose to a maximum value of 125 : calcium deficiency was evident after the second harvest (i.e. after 100 days) : and relative yields for the K_0 treatments held at more than 75 for approximately 81 days.

7. In "*Lateritic Sand*" relative yields for the P_0 treatments did not exceed a mean value of $64 \pm 5{\cdot}8$ for the second and third harvests, but there was evidence of further improvement in the fourth harvest : calcium deficiency was evident after the first harvest (i.e. after only 50 days). Relative yields

for the K_0 treatments fell less rapidly, and there was evidence of a decreasing capacity for K.-fixation.

8. Assuming that all three soils are derived from the one, or similar, parent material, it would appear that the "*Lateritic Loam*" represents the highest stage of development (i.e. the most fertile soil), and the "*Lateritic Sand*" a leached, or degraded derivative therefrom.

9. If that is so, and in view of current observation that this soil is highly erodible, then a first consideration in estate management—on these soils—should be to retain that soil above the "*Lateritic Gravel*", and on the relatively high ground where it is formed. The construction and maintenance of properly designed contour banks, provision of adequate ground cover, and indeed all forms of soil conservation and erosion control would seem to be fundamental requirements and essential to any form of good management.

10. From the national view point this is even more important; since the data from these experiments suggest that erosion and transportation of that soil to the valley floors is followed by severe leaching and loss of very great natural resources.

11. Adequate control of erosion would also have an appreciable effect on fertilizer requirements for "*Lateritic Gravel*" and "*Lateritic Loam*"; since the two soils require differing amounts of P. and K., and correct dosage would vary according to the amount of loam retained or lost by erosion.

12. While no precise recommendation is possible at this stage, it can be said that both soils would benefit from some addition of calcium (tentatively 5-10 cwt./acre $CaCO_3$). Application of potassium ($4\frac{1}{2}$ cwt./acre K_2SO_4) is likely to have markedly beneficial effects, but the optimum dosage is subject to considerable reduction where cultivation and aeration is practicable.

Both soils would benefit from an initial dressing of phosphate (equivalent to 80 lb. P_2O_5/acre), but there is a very real danger of over-dosage from repeated applications.

13. Both soils show an acute deficiency of nitrogen, and use of green manures, and/or application of frequent, small doses of nitrogenous fertilizers ($(NH_4)_2SO_4$ or NH_4NO_3) can be recommended.

14. The nutrient status of "*Lateritic Sand*" is very similar to that of the "*Cinnamon Sand*" and pending results from some further experiments, the same type of fertilizer mixture is recommended. Boron—which is incorporated in that mixture—need not be applied.

4. ACKNOWLEDGMENT

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HERITABILITY OF GRAIN SHEDDING AND OTHER CHARACTERS IN RICE*

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FROM THE STAND POINT of practical plant breeding, it is of importance to know how genetically superior individuals should be selected from a hybrid population. Such selection is easily effected in genetically simple characters such as glutinosity. On the contrary, it is very difficult to deal with most of the economically important characters of rice, as they are apt to be influenced by environmental factors such as temperature, soil fertility, water depth, &c. The recent progress in biometrical genetics has contributed much to overcome this difficulty. These advances have made it possible to separate the genetic variation from the environmental effects. Though studies on the measure of genetic variation in terms of heritability have been few in the case of rice, much knowledge has accumulated about the other important crops (1, 2, 3 & 4).

This paper deals with the estimation of the heritability values of a few of the economically important characters of rice. Grain shedding is one of them. The tendency for the grain to shed prematurely is one of the serious defects of some of the varieties of this country. The high shedding character of *Pachchai perumal* 2462/11, a variety widely grown during the *yala* season in the dry zone, was corrected by the junior author by transferring the low shedding factors of *Vellai illankalayan* 28061. The data collected in the early generations of this cross and a cross between *Panduruwi* and *Vellai illankalayan* 28061 are used in this paper for the estimation of heritability. The other characters dealt within this paper are panicle length and the plant height.

MATERIALS AND METHODS

The F_2 populations of the two crosses referred to above were grown in single-spaced plots and a number of individual plants were selected at random. In the F_3 generation seeds from the random plants were grown in progeny rows. The parental varieties were grown similarly. Measurements and other records were taken on each individual plant. Grain shedding was assessed by running a glass roller over each of the panicles placed on an inclined board.

* A paper read at the annual sessions of the *Ceylon Association for the Advancement of Science* held at Colombo in December, 1957.

The heritability values of characters were estimated by the analysis of variance of the F_3 data and by partitioning the variance components.

The method of estimating the heritability value is as follows :—

Let the number of F_3 lines be x
the number of individuals within each line be .. y
the number of individuals within a parental variety plot be .. z
and the number of parental pureline varieties be .. r

Then on the basis of measurements taken on each individual F_3 plant, the following analysis of variance table can be constructed.

TABLE I

Source of Variation	*Degrees of of Freedom*	*Mean Squares*	*Expected Composition of Mean Squares*
Between lines ..	x—1	M_1	$\sigma^2 + a\sigma^2$
Within lines ..	x(y—1)	M_2	σ^2
Total ..	xy—1		
Within pureline varieties ..	r(z—1)	M_3	σ_e^2

Where σ_e^2 stands for environmental variance.
σ^2 includes besides environmental variance, genetic variance due to segregation of genes within F_3 lines.
σ_s^2 is the genetic variance due to genetic differences between lines.

The genetic variances involved in σ^2 and σ_s^2 are expected to be as follows, in the case of F_3 hybrid lines of autogamous plants.

$$\sigma^2 = \sigma_e^2 + \sigma_w^2$$

or $$\sigma_w^2 = \sigma^2 - \sigma_e^2 = \tfrac{1}{3}\sigma_g^2 + \tfrac{2}{3}\sigma_h^2 \quad \ldots\ldots\ldots\ldots (1)$$

$$\sigma_s^2 = \tfrac{2}{3}\sigma_g^2 + \tfrac{1}{3}\sigma_h^2 \quad \ldots\ldots\ldots\ldots (2)$$

In the above analysis of variance table, a = y provided the same number of individuals are measured in each line. If there are variations in the number of individuals in lines, then the following formula of Crump (5) is applicable.

$$a = \frac{1}{l-1}\left\{N - \frac{1}{N}\sum_{i=1}^{e} n_i^2\right\} \quad \ldots\ldots\ldots\ldots (3)$$

where l = number of lines
N = total number of individual plants in all lines
N_i = number of individuals in ith line.

In Table 1, setting M_3 equal to σ_e^2, $(M_2 - M_3)$ will be σ_w^2 and $(M_1 - M_2)/a$ will be σ_s^2. Thus the estimated values of σ_g^2 and σ_h^2 can be determined. These two are the components of genetic variance that are fixable and non-fixable respectively in the F_3 generation. Based on the above, the heritability value h^2 of the F_3 generation can be estimated thus :

$$h^2_{(F_3)} = \frac{\sigma_g^2}{\sigma_g^2 + \sigma_h^2 + \sigma_e^2} \quad \ldots\ldots(4)$$

The heritability value can be corrected and made applicable to the F_2 generation. If the component of genetic variance which is fixable in the F_2 generation is $\sigma_{g'}^2$ and that which is non-fixable is $\sigma_{h'}^2$ then,

$\sigma_{g'}^2 = \frac{2}{3} \sigma_g^2$ and
$\sigma_{h'}^2 = \frac{4}{3} \sigma_h^2$ (Sakai 6)

Hence, from the analysis of variance of the F_3 progenies, the heritability value of the F_2 generation can be computed thus :

$$h^2_{(F_2)} = \frac{\sigma_{g'}^2}{\sigma_{g'}^2 + \sigma_{h'}^2 + \sigma_e^2} = \frac{\frac{2}{3}\sigma_g^2}{\frac{2}{3}\sigma_g^2 + \frac{4}{3}\sigma_h^2 + \sigma_e^2} \quad \ldots\ldots(5)$$

The regression of the F_3 progeny lines on the F_2 parents were also computed This regression coefficient expresses the heritability value of the F_2 generation.

EXPERIMENTAL RESULTS

The heritability value of the grain shedding character of a cross between *Pachchai perumal* 2462 11 and *Vellai illankalayan* 28061, estimated by the analysis of variance of the F_3 data, is given below in detail.

TABLE 2

Source of Variation	*D.F.*	*Sum of Squares*	*Mean Squares*	*Expected Composition of Mean Squares*
Between lines	17	1261·51	74·2064	$\sigma^2 + a\,\sigma s^2$
Within lines ..	250	2971·62	11·8865	σ^2 ($= \sigma e^2 + \sigma w^2$)
Total ..	267	4233·13		
Within parental pure-line varieties ..	28	140·14	5·0050	σ_e^2

$a = 14{\cdot}888$ by formula (3)

$\sigma_e^2 = 5{\cdot}0050$

$\sigma_w^2 = 6{\cdot}8815 = \frac{1}{3}\sigma_g^2 + \frac{2}{3}\sigma_h^2$ .....(1)

$\sigma_s^2 = 4{\cdot}1859 = \frac{2}{3}\sigma_g^2 + \frac{1}{3}\sigma_h^2$ .....(2)

Based on (1) & (2) $\sigma_g^2 = 1{\cdot}4903$

and $\sigma_h^2 = 9{\cdot}5771$

Therefore, the heritability values of grain shedding for the F_3 and F_2 generations, based on the formulae (4) and (5) will be as follows :—

$h^2_{(F_3)} = 0{\cdot}093$

$h^2_{(F_2)} = 0{\cdot}053$

Similarly, the heritability values were computed in the case of a few other characters of rice. These values, as well as the calculated regression coefficients of F_3 progenies on F_2 parents are given below in Table 3. The heritability values estimated with other hybrid populations in Japan by Oka (7), a colleague of the senior author of this paper, are given in the last column.

TABLE 3

Characters	*Cross No.*	h^2		b	$h^2_{(F_2)}$ *(Oka 1955)*
		F_2	F_3		
Grain Shedding ..	1	0·053	0·093	0·082	—
Do. ..	25	0·300	0·392	0·239	
Panicle length ..	1	0·041	0·069	0·155	0·237
Do. ..	25	—	—	0·099	
Plant height ..	1	0·481	0·612	0·465	0·317

The number of effective factors concerned in the case of the above characters was studied using the following formula (Mather 8) :—

$$k = \frac{[(\bar{P}_1 - \bar{P}_2) \div 2]^2}{2\sigma_{g'}^2} \quad \text{.....(6)}$$

where $\bar{P}_1$ and $\bar{P}_2$ = values of the two parental varieties respectively.

k = number of effective factors.

The results of computation are given in Table 4.

TABLE 4

Characters	*Cross No.*	*k*	$\bar{P}_1$	$\bar{P}_2$	σg^2
Grain shedding (Per cent transformed to degrees) ..	1	6	19·88	13·12	0·9936
Dc. ..	25	2	21·60	13·06	3·9407
Panicle length (cms) ..	1	11	17·77	23·51	0·3678
Plant height (cms) ..	1	3	79·37	129·83	99·0900

DISCUSSION AND CONCLUSIONS

Heritability is an index for the efficiency of selection. In the case of characters which possess high heritability values, selection in the early generations will be quite effective, whereas it will not be so in the case of characters which have low values of heritability. That the value of heritability is low means that either the dominance effect of genes or the effect of environment or both are great as far as hybrid populations are concerned. In most of the economically important quantitative characters of autogamous cereals, like rice, the heritability in the F_2 generation is so low that it is not possible to select superior genotypes among the segregating plants of a hybrid population. However, the heritability increases gradually with successive generations due to the decline in heterozygosity, resulting in the decrease in action of non-additive genes.

The results of the present investigations show that the values of heritability for grain shedding are as low as 0·05 in one cross and 0·30 in another. Panicle length is also found to have a low heritability value, whereas in the case of plant height the value is fairly high. The value of heritability however varies, depending upon the genetic nature of hybrid populations. In the case of these crosses, it can be concluded that individual selection in the F_2 generation for either grain shedding or panicle length will be worthless. This fact is indicated graphically in Fig. 1 which shows the relation between the F_2 —plant-values and the F_3 — progeny-values of grain shedding. It is evident from this figure that the F_2 plants which exhibit low values of shedding (viz. : Nos. 13, 19, 11 and 16) do not give rise to F_3 progenies with similar values. It is also indicated to be so in the case of F_2 plants having high values of shedding. Figure 2 shows the relation between F_2 — plant-values and F_3 — progeny-values of plants height, which has fairly high heritability. In this case, the F_3 — progeny-values show similarity to the F_2 — plant-values.

The number of effective factors responsible for grain shedding was found to be 6 and 2 in two different cross combinations. In the case of panicle length and plant height it was found to be 11 and 3 respectively. These facts also substantiate the earlier conclusions.

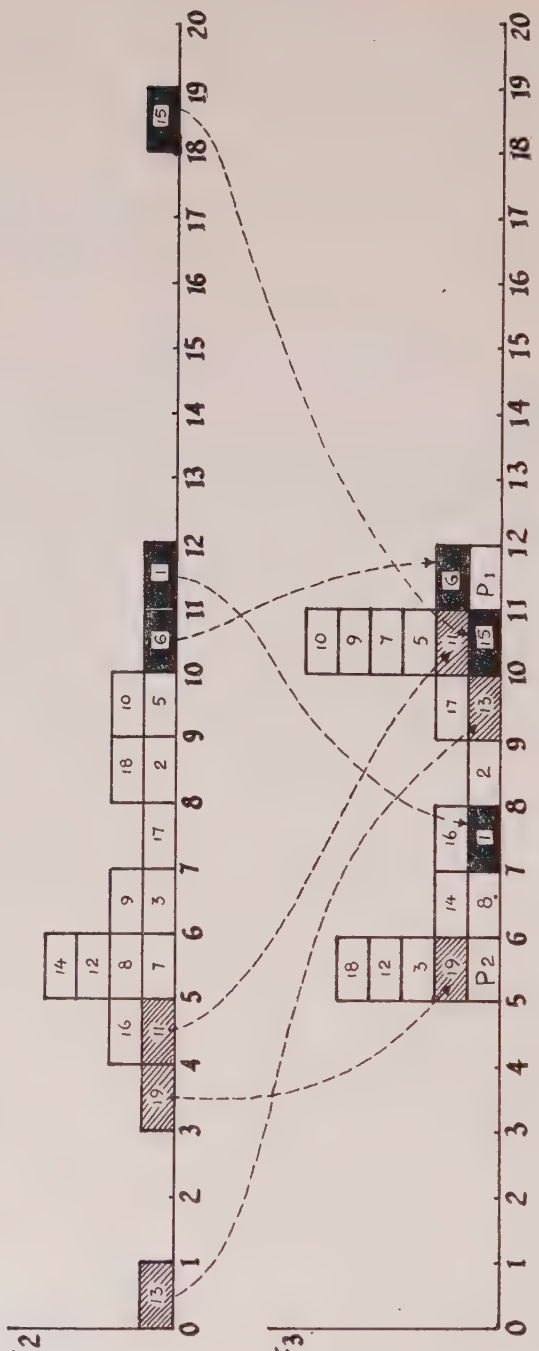

FIG. 1—EFFECT OF SELECTION ON GRAIN SHEDDING IN F_2 GENERATION

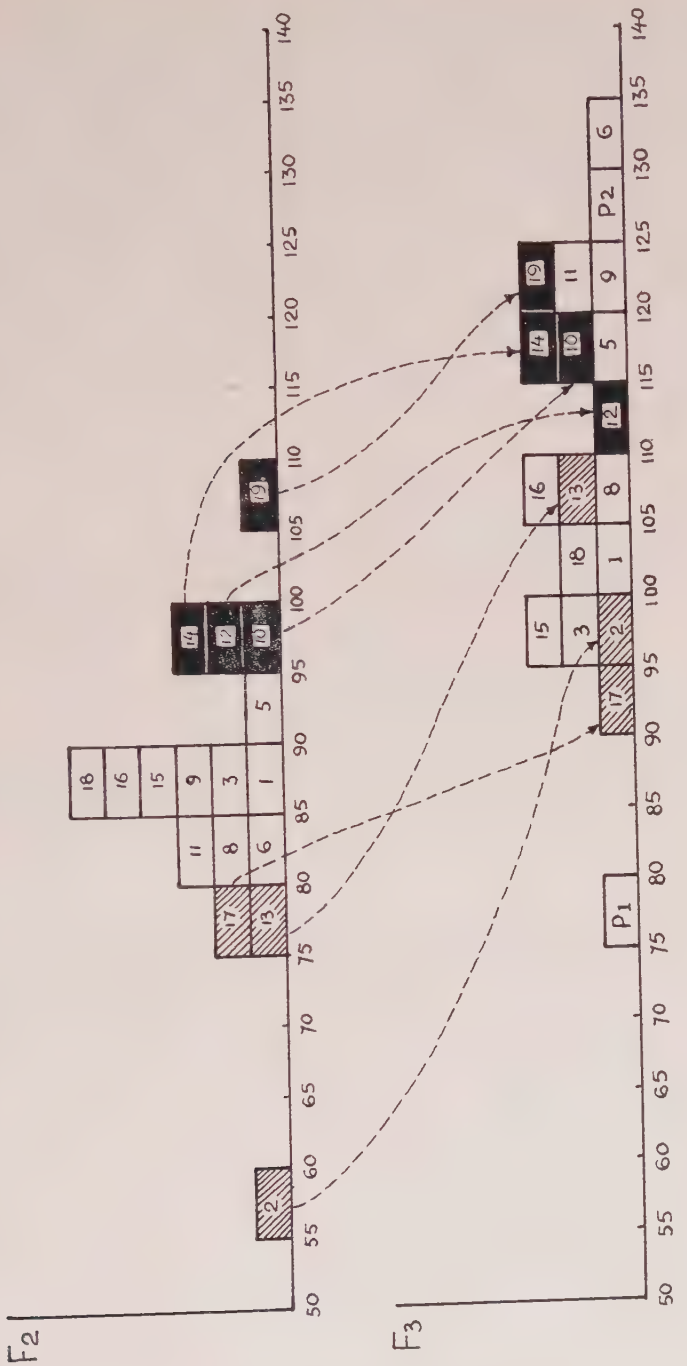

FIG. 2—EFFECT OF SELECTION OF PLANT HEIGHT IN F_3 GENERATION

SUMMARY

This paper deals with the estimation and use of the heritability values of a few economically important characters of rice in hybrid populations.

The heritability values of grain shedding and panicle length are shown to be low and that of plant height to be fairly high.

The number of effective factors responsible for these characters have been determined.

These facts suggest that selection of individuals for grain shedding as well as panicle length in F_2 populations may be ineffective, unlike in the case of plant height. Selection for such characters as grain shedding or panicle length, which have low values of heritability, should be delayed till later generations.

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SOME FERTILIZER STUDIES ON *BRACHIARIA BRIZANTHA* IN THE DRY ZONE OF CEYLON*

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One of the most useful pasture plants ever introduced to this Island is *Brachiaria brizantha*—an introduction from East Africa. It has proved successful under a wide range of climatic conditions in Ceylon and as such it is bound to play an important role in our dry zone agriculture. With its increasing popularity, the total acreage under this grass has risen considerably during the last few decades and is estimated to be over 10,000 acres (2). One must admit that in this field of grassland husbandry our information is woefully inadequate. To date, no information whatsoever is available regarding the full potentialities of this pasture grass in Ceylon. It is not known what factors contribute towards its yield and chemical composition. The main object of this study was to compare the effect of differential dressings of nitrogen, phosphate and potash on the yield and chemical composition of a *Brachiaria* pasture. In this paper, the results of the first harvest year are reported.

EXPERIMENTAL LAY-OUT AND PROCEDURE

The experimental field was located in the Land Class III of the Dry Zone Research Station, (1), Maha Illuppallama. This field which carried a Napier crop (*Pennesetum purpureum*) in the previous year was planted to *Brachiaria* in December, 1955. During the first year of establishment, a single application of nitrogen, at the rate of 1 cwt. of sulphate of ammonia was given and the field was grazed three times to allow a successful establishment of the grasses. The experiment was laid down in *maha* 1956/57 and fertilizer applications were made in November, 1956, and April, 1957. Analysis of soil samples taken prior to the application of fertilizers showed no appreciable local variation in the soil nitrogen, P_2O_5 and K_2O content. The relevant physical and chemical analysis on this soil type are presented in Table 1.

* Contribution No. 3 from the Division of Dry Zone Research.

TABLE I

Particle Size Analysis

Particle size fraction	4–0·2 mm.	0·2—·02 mm.	·02 mm.–2μ	< 2μ
Per cent particles	39·3	24·5	8·6	27·8

Chemical Analysis (Total fusion)

SiO_2	78·23 per cent
Al_2O_3	13·70 ,,
Fe_2O_3	5·40 ,,
MnO	0·04 ,,
TiO_2	0·68 ,,
CaO	1·06 ,,
MgO	0·36 ,,

Chemical Analysis (Constant boiling HCL Extract)

P_2O_5	0·03 per cent
K_2O	0·10 ,,

Available P_2O_5 0·00035 per cent.
(2N ammonium acetate + IN H_2SO_4 extract)

Exchangeable Cations (m.e./100 grm.)

Ca	Mg	K	Na
8·1	1·6	0·81	0·06

The experiment was of the 3×3×3 NPK type, replicated twice and the 54 plots arranged in 6 blocks, thus comparing the effects of all combinations of nitrogen, phosphate and potash. The treatments were as follows :—

- N_0 = No Nitrogen
- N_1 = 40 lb. Nitrogen/acre as Ammonium Sulphate (20·6%N)
- N_2 = 80 lb. Nitrogen/acre as Ammonium Sulphate (20·6%N)

- P_0 = No phosphate
- P_1 = 40 lb. P_2O_5 per acre as Superphosphate (18% P_2O_5)
- P_2 = 80 lb. P_2O_5 per acre as Superphospha+e (18% P_2O_5)

- K_0 = No Potash
- K_1 = 20 lb. K_2O per acre as Muriate of Potash (48% K_2O)
- K_2 = 40 lb. K_2O per acre as Muriate of Potash (48% K_2O)

The size of each plot was 1/100 of an acre and cuts were taken at intervals of 6 weeks from an area 3 ft. × 15 ft. in the centre of each plot. All cuts were made with an Allen motor scythe with a fine cutter bar assembly. Yields of fresh material were recorded and samples were taken for dry matter determination and chemical analysis.

During the experimental period, three herbage cuts were taken, two in the *maha* season and one in the *yala* season. It was intended to take two cuts in the *yala* season as well, but the rate of herbage production was too poor to permit a second cut in this season. In this paper, however, the results of each harvest, immediately following the application of fertilizers, are reported and these will be referred to as *maha* and *yala* cuts respectively.

WEATHER

Details of the rainfall distribution during the period of this investigation, the mean monthly rainfall (average for 50 years) and the maximum and minimum temperature (average for 12 years) are given in Table 2.

TABLE 2—Weather Data

	Maha						*Yala*			
	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June
Rainfall (1956-57) (ins.) ..	Nil	5·20	7·20	5·08	2·63	3·33	0·42	9·23	6·65	1·18
No. of rainy days ..	Nil	17	21	14	11	9	2	16	17	11
Rainfall Av. for 50 years	3.0	9·41	10·0	8·0	5·5	1·9	4·6	7·2	4·2	1·3
Av. No. of wet days ..	6	15	17	13	10	4	7	10	5	3
Mean maximum Temp. °F	91·2	88·1	85·6	83·0	83·5	87·9	92·0	91·3	90·2	90·1
Mean minimum Temp. °F	74·7	73·3	70·5	70·0	69·3	68·5	71·5	73·9	76·3	76·1

The rainfall distribution during the two growth periods may be considered excellent for the growth of grass.

RESULTS

1. Effect of Nitrogen on the Per cent Dry Matter. Holmes (5) found that nitrogenous fertilizers reduced the percentage dry matter content of herbage appreciably, the herbage from the no-nitrogen treatments contained 25 per cent dry matter while the heavily manured plots had 19 per cent dry matter. Intermediate values of dry matter were obtained for moderate dressings of nitrogen.

As seen in Table 3, in each case, the addition of nitrogenous fertilizer resulted in a reduced percentage of dry matter in the herbage, thereby causing considerable losses of dry matter, but this was more than compensated by the higher production of herbage from nitrogen-treated plots. This effect was most apparent with the cuts immediately following fertilizer applications. Phosphate and potash had no effect on the per cent. dry matter

TABLE 3—Per cent. Dry Matter in Herbage

	N_0	N_1	N_2
Maha ..	31·7	24·8	22·5
Yala ..	28·5	24·7	21·5
Mean ..	30·1	24·7	22·0

2. Effect of Fertilizers on the Yield of Dry Matter. As none of the interactions proved significant, only the main effects are presented in Table 4.

TABLE 4—Yield of Dry Matter (lb. per acre)

	N_0	N_1	N_2	P_0	P_1	P_2	K_0	K_1	K_2	*Mean*	*Significant Diff.*
Maha	1931	4101	4559	3134	3769	3688	3479	3539	3550	3528	588
Yala	1036	2960	3670	2098	2914	2812	3473	2471	2547	2553	410
Mean	1483	3530	4114	2616	3341	3250	2976	3005	3048	—	—
Relative Yield	100	238	277	100	127	124	100	101	102	—	—

Both cuts gave marked increases in the yield of dry matter to nitrogen but the increases were by no means proportional to the quantities of nitrogen applied. The average increase was 2047 lb. per acre for 40 lb. nitrogen and a further 584 lb. per acre for an additional 40 lb. of nitrogen. The average increases at different levels of nitrogen for *maha* and *yala* were of the same order but the total production of herbage in *maha* exceeded the *yala* season. This variation in total yield could be attributed to the more favourable climatic conditions of the former period.

Phosphates had very small effects compared with nitrogen and the average responses to 40 lb. and 80 lb. P_2O_5 were 726 and 634 lb. dry matter per acre respectively. Both levels of applied P produced a significant response over P_0 but the differences between P_1 and P_2 were not statistically significant. It is interesting to note that phosphates gave very big increases in the yield of dry matter in the presence of nitrogen (Table 5).

TABLE 5—Yield of Dry Matter (lb. per acre)

	Maha			*Yala*		
	P_0	P_1	P_2	P_0	P_1	P_2
N_0	1712	2065	2015	794	1288	1029
N_1	3455	4248	4600	2376	3306	3194
N_2	4235	4994	4448	3124	4152	3736

Applications of potash had no noticeable effects on the yield of dry matter either in the absence or presence of nitrogen. In the second cut of the *maha* season (the results of which are not reported in this paper) residual effects were manifested only at the higher level of nitrogen application.

3. Effect of Nitrogen on the Per cent Crude Protein and Yield of Crude Protein. Nitrogen produced a very significant increase in the per cent crude protein and yield of crude protein, as seen in Table 6, while phosphate and potash had no effect on the crude protein content for any cut.

TABLE 6—Per Cent Crude Protein and Yield of Crude Protein (lb. per acre)

	Per cent Crude Protein				*Yield of Crude Protein*			
	N_0	N_1	N_2	*Significant Dif.*	N_0	N_1	N_2	*Significant Difference*
Maha	6·09	7·77	10·39	0·36	117	319	475	60
Yala	5·50	6·73	8·91	0·63	56	201	328	108
Mean	5·78	6·75	9·65		86	260	401	

Considering the average effects for both *maha* and *yala* cuts, in the last line of the table, it is clear that nitrogen raised the per cent crude protein content of herbage. The *maha* application resulted in producing a herbage with higher percentage crude protein than the *yala* application.

At all levels of application of sulphate of ammonia, the yield of crude protein was greater than the control and the greatest production resulted from the highest level of nitrogen. This is correlated with the higher yield of dry matter and crude protein percentages produced by nitrogen applications.

4. Effect of Nitrogen and Phosphate on the Per cent P_2O_5 in Dry Matter. In Table 7, it is observed that the application of phosphate increased the P_2O_5

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status of the herbage for each increment of phosphate applied. This could be anticipated from this soil which is relatively poor in phosphate.

TABLE 7—Per Cent P_2O_5 in Dry Matter

	MAHA				*YALA*			
	P_0	P_1	P_2	*Mean*	P_0	P_1	P_2	*Mean*
N_0	0·28	0·43	0·55	0·42	0·43	0·54	0·71	0·59
N_1	0·28	0·39	0·50	0·39	0·29	0·48	0·54	0·44
N_2	0·26	0·35	0·50	0·37	0·25	0·54	0·57	0·45
Mean	0·27	0·39	0·52	—	0·32	0·52	0·61	—

Diverse opinion exists with regard to the P_2O_5 uptake of nitrogen-treated herbage. Most investigations (3, 8) have shown a depression in the P_2O_5 content when nitrogen is applied to grassland, while Greenhill and Page (4) reported a positive correlation between nitrogen and phosphates. Walker *et al.* (8) found that nitrogen reduced the P_2O_5 content of herbage in the absence of phosphate or in phosphate deficient soils, whereas it increased the per cent P_2O_5 on phosphate rich soils.

As seen in Table 7, in the *maha* cut, nitrogen decreased the P_2O_5 content very slightly in the presence of P, whilst in the absence of P, the P_2O_5 content remains almost unchanged.

In the *yala* cut, however, with the exception of one treatment the depression was more pronounced both in the presence and absence of phosphate. It would be difficult to attribute this phenomenon solely to the phosphate status of soil. Further fundamental studies on the interaction between the applied phosphates and the sesquioxide constituents present in soil would be necessary.

5. Removal of P_2O_5 in Herbage. The average quantities of P_2O_5 removed by the herbage at different nitrogen levels are recorded in Table 8.

TABLE 8—Removal of P_2O_5 in Herbage (lb. per acre)

	MAHA				*YALA*			
	P_0	P_1	P_2	*Mean*	P_0	P_1	P_2	*Mean*
N_0	4·6	8·8	11·0	8·1	3·4	6·9	7·30	6·8
N_1	9·6	16·5	23·0	16·3	6·8	15·8	17·2	13·3
N_2	11·0	17·4	22·2	16·8	7·8	22·4	21·2	17·1
Mean	8·4	14·2	15·4	—	6·0	15·0	15·2	—

The results indicate that increasing levels of sulphate of ammonia increased the amount of P_2O_5 removed, at each increment of phosphate applied. It is also seen that the heaviest removal of phosphate was in the presence of both nitrogen and phosphate.

DISCUSSION AND PRACTICAL IMPLICATIONS

The influence of nitrogenous fertilizer on productivity and nutrient value of some temperate species of pasture plants and its interaction with pasture legumes have recently been reported (3, 6). This study was undertaken in the dry zone of Ceylon with a view to :—

1. determining the responses to nitrogen, phosphate and potash as measured by productivity and nutrient value of pasture herbage ;
2. assessing the optimum dressings of nitrogen, phosphate and potash.

Nitrogenous manuring of grassland differs from phosphate and potash manuring in two important respects. Phosphates and potash could be applied to pasture over a wide range of conditions without risk of doing harm even under conditions of poor management. On the other hand considerable harm can result from application of nitrogen to grass in soils lacking in the more important minerals. The phosphate and potash requirements of grasses can be supplied by the soil from its natural reserves or by supplementing the soil with these fertilizers. The nitrogen nutrition of the grass sward, on the other hand, is facilitated by fixation of atmospheric nitrogen by bacteria present in the soil or on roots of legumes. Some of this fixed nitrogen becomes available for grass and under certain conditions high output can be maintained without recourse to artificial nitrogen. This is particularly the case in New Zealand (7).

In the dry zone of Ceylon, where suitable pasture legumes have not been developed yet, high grassland production as in temperate countries is not possible. Moreover, there is heavy leaching of nitrogen during the *maha* rains from October to December. The nitrate content of the soil under an unfertilized *Brachiaria brizantha* sward was 0·40 p.p.m. prior to the rains. With the initial light rains it increased to 3·02 p.p.m. of nitrate. With the subsequent heavy rain, the nitrate content of the soil dropped to 0·20 p.p.m. In addition to this, the normal loss of nitrogen through grazing is substantial. The net result is that all our pastures require nitrogen at the beginning of the season, when the supply of grass is vital. Grass is relatively a heavy feeder, particularly of nitrogen, and a high level of grass production requires a liberal supply of one or more of the major nutrients.

The evidence obtained in this trial has indicated that for pasture establishment, a single dressing of 1 cwt. of ammonium sulphate two to three weeks after planting is beneficial. Nitrogen applications stimulated the growth of

grass to such an extent that it reached the grazing stage a few weeks earlier than the no nitrogen plots. It must be pointed out that owing to the remarkable and immediate response to application of sulphate of ammonia on these plots, nitrogen as a plant nutrient was in short supply and that under these conditions one must experience larger responses to nitrogen when it has been applied. After the first cut of the *maha* season, measurable residual effects were obtained only at the higher levels of nitrogen application. It is possible that at heavy rates of application during the *maha* season, the period of heavy rainfall, the fertilizers may be largely wasted on account of leaching. There seems little justification for using heavy doses of nitrogen during this period, if high productivity is the ultimate aim. If on the other hand a very high crude protein content of the herbage is required, the application of heavy doses appears justifiable. Furthermore, in order to increase productivity, the possibility of applying split dressings of nitrogen would seem worthy of investigation under conditions of heavy rainfall.

By contrast, the responses to P were much smaller than for nitrogen but both levels of added P produced significant increases in the yield of dry matter. Application of 40 lb. and 80 lb. P_2O_5 resulted in an average increase of 726 lb. and 634 lb. dry matter per acre, respectively. Therefore it would appear from evidence available that in these soils an optimum dressing of superphosphate should rarely exceed 40 lb. P_2O_5/acre.

Application of phosphate always increased the P_2O_5 content in herbage. Since phosphates are considered important in animal nutrition, their value cannot be assessed solely by the amount of dry matter produced. Also, the heaviest removal of P_2O_5 in herbage was in the presence of both nitrogen and phosphate and the big increases obtained from nitrogen concomitantly increased the demand for phosphate. It is possible that the beneficial effect of phosphates would be increased by periodic dressings of nitrogen.

As would be expected from the chemical analysis of the soil, there was no response to potassium.

SUMMARY

In the experiment described, sulphate of ammonia increased the production and protein status of pasture herbage. The average increases were 2,047 lb. dry matter for 40 lb. nitrogen and 2,631 lb. dry matter for 80 lb. nitrogen per acre respectively. Measurable residual effects were obtained only at the higher level of nitrogen. It appears that in the absence of a pasture legume, nitrogen is essential to secure high yields. Phosphates may be relied on to increase productivity and enhance the nutrient value of herbage. The yield of P_2O_5 removed in herbage also increased with the amount of nitrogen and phosphate applied. The beneficial effect of P is appreciably increased in the presence of nitrogen.

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RESISTANCE TO BENZENE HEXACHLORIDE OF THE RICE BUG *LEPTOCORISA VARICORNIS*, F. (FAM. COREIDAE ORD. HEMIPTERA) AND ITS INSECTICIDAL CONTROL

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INTRODUCTION

In his investigations on insect control in Ceylon using the then newly introduced insecticides DDT and gamma benzene hexachloride (gamma BHC) Baptist (1947) found that *Leptocorisa varicornis* F. the rice bug was easily controlled by dusts of gamma BHC. Since these investigations, low percentage (.35 per cent) gamma BHC dusts have been recommended and used for the control of the pest in this country. In recent times however there have been numerous reports from the field that gamma BHC dust was not giving the control results it used to against this pest. This observation might have resulted from one or more of the following causes, viz., (*a*) development of resistance of *L. varicornis* to gamma BHC, (*b*) deterioration of the quality of the formulation of BHC used or (*c*) faulty application of the dust during seasons of particularly high pest incidence. The investigation being reported upon was conducted with a view to elucidating the factors responsible for the poor control of the pest as reported from the field.

IMPORTANCE OF L. VARICORNIS AS A PEST OF RICE TO CEYLON

The bug *Leptocorisa varicornis* is found in all parts of Ceylon. When no flowering paddy is available for feeding, the bugs are to be found on wild grasses and on paddy plants in small numbers. As soon as the flowering commences the bugs migrate from wild grasses to the paddy plants to feed upon the freshly set grains. This diet apparently stimulates reproduction and the pest usually multiplies into enormous proportions if not checked early.

In areas where several varieties of paddies have been sown and also where sowing has been spread over a long period, resulting, in both cases, in flowering being spread over a considerable period of time, the conditions are ideal for pest multiplication. Similar enormous build-up of paddy bug populations occur where a single variety of paddy has been sown but for some reason, such as poor adaptation to the area, tillering is vigorous and prolonged and flowering similarly prolonged.

The damage by the rice bug *L. varicornis* to the rice crop in Ceylon is universal and this pest should be regarded as the worst pest on rice in Ceylon. Light infestations if not checked early will cause some damage as the pest is a voracious feeder. Heavy, unchecked infestations on the other hand completely destroy the harvest. Instances are recorded during the past few years where cultivators, unaware of effective insecticidal control measures, have been compelled to introduce buffaloes into their mature paddy tracts to trample the crop down because harvesting of the crop destroyed by the paddy bug proved entirely uneconomical.

IMPLEMENTATION OF CONTROL MEASURES IN THE VILLAGES

Various cultural and mechanical methods have been from time to time recommended for the control of this bug. Among these have been the sowing within as short a period as possible of rice varieties of the same age for maturity within as short a period of time as possible, the slashing of wild grasses in the neighbourhood of rice tracts before the rice flowers and the use of ropes coated with the latex of the jak fruit for capturing the pest. While the cultural methods, more often than not, could not be implemented either for economic or other reasons, the mechanical method of control recommended was relatively ineffective when implemented.

At present, apart from those areas where the " kemma " or " charm " is practised and the rare instances where the " latexed " rope is in use, the chemical method of control has gained considerable application. However there are many rice-growing areas still in this country where dusting with BHC for the control of the rice bug has never been seen by cultivators. In those areas where dusting is practised, it cannot be said that the dusting is always done in a manner that would result in maximum effectiveness against the pest. The devices used for the application of the insecticidal dusts ranged from a muslin bag used as a container for the dust held aloft at the end of a stick and vigorously shaken to disperse the dust to the dust " gun " or a rotary hand duster. Dusting with the muslim bag or dust gun usually gave poor dispersal of the dust while the use of the rotary hand duster alone gave

the required dispersal of insecticide. In most cases the rate of application of dust ranged between 2 and 5 lb. of dust and not the recommended 10 to 15 lb. of dust per acre. A careful analysis of the situation obtaining in the field in regard to control of the rice bug suggests that inadequate methods of application of the insecticidal dust for its proper dispersal and the administration of insufficient quantities of dust per acre lead in most cases to poor control of the pest during seasons of high pest incidence. This same situation provides the ideal conditions for the development of resistance by the pests.

STUDIES ON RESISTANCE OF L. VARICORNIS TO GAMMA BHC AND SUSCEPTIBILITY TO SERIES OF OTHER INSECTICIDES

Adult *L. varicornis* were collected daily from the field in the mornings and conveyed to the laboratory. These collections were made from a series of localities involving areas where insecticidal control had never been applied against the pest, where BHC had been used for a few years and also where BHC had been used for at least 8 years every season. In the laboratory the most active bugs were sorted out into 300 cc. conical flasks at the rate of 25 bugs per flask. Each flask was supplied with a wad of cotton soaked in water and suspended by a thread from the mouth of the flask. The flask was also supplied with paper strips suspending from the cotton plug at the mouth to the bottom of the flask to provide walking space for the bugs. Bugs were then allowed to rest for about one hour in this condition before treatment in the evenings.

Anaesthesia such as with carbon dioxide was found unnecessary as a preparation of the bugs for topical administration of measured dosages of insecticide. Bugs were instead first collected at the bottom of the flasks by removal of the cotton plug and paper strips and the wet cotton wad and the slight tapping of the flask on the table. The mouth of the flask was then vigorously directed by a sharp jerk on to the centre of a 1 square foot pad of cotton wool with a loose surface of fibres. The cotton wool was then folded into two enclosing the bugs and raised only slightly to remove a bug at a time for treatment. The presence of the fine cotton fibres impeded both free movement and escape of the bugs. Bugs were treated topically on the venter of the abdomen with various concentrations of gamma BHC in acetone solution. One cubic millimeter of the acetone solution of the insecticides was the standard quantity of liquid applied. The acetone was evaporated immediately after treatment by blowing softly and the treated bugs replaced in the flask. At least 100 bugs were employed in each test dosage of gamma BHC. The insecticidal solutions were

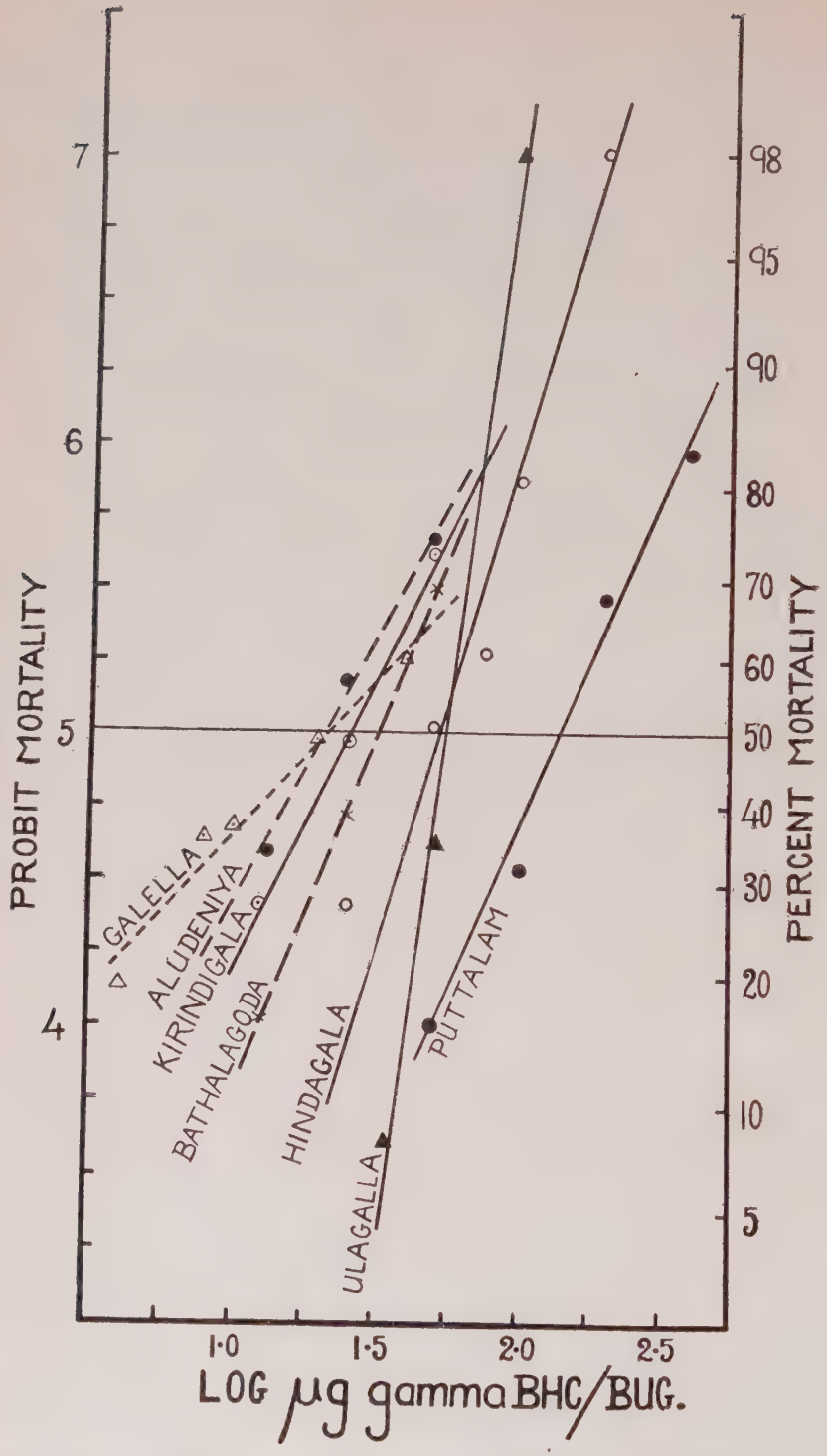

PLATE 1. Susceptibility and tolerance of a series of strains of *Leptocorisa varicornis* to gamma BHC administered by topical application.

administered by way of a 26 G hypodermic needle fixed on to a 1 cc. tuberculin syringe, the plunger of which was operated by a micrometer screw as described by Trevan (1922).

Treated bugs were placed in a chamber at a constant temperature of 30° C. and constant humidity of 92 per cent, and mortality counts taken every 12 hours. Bugs, knocked down on their backs and unable to regain their feet, were regarded as dead. The results of these studies are expressed graphically in Plate 1 and in tabular form in Table 1.

Plate 1 and Table 1 show clearly that the Puttalam strain is the most resistant of the seven strains of the bugs studied, being as much as 6.6 times more tolerant to gamma BHC than the Aludeniya and Galella strains which were the most susceptible to BHC. Inquiry in each of the seven localities from which bugs were collected for study confirmed that at Galella and Aludeniya insecticidal treatments had never been conducted against the rice bug. At Kirindigala only sporadic and recent treatments with BHC dusts had been carried out against the pest. At Bathalagoda the bugs were collected from the Paddy Station where BHC dusts have been applied for the last 8 or 9 years. The same situation prevailed at Hindagala, Ulagalla and Puttalam. The situation at Puttalam was somewhat different from that of the others in that the high degree of resistance and difficulty to control the pest with BHC dusts was only noted in a 15-20 acre tract isolated and surrounded by high forest for at least 5 miles.

The action of a series of chlorinated hydrocarbon and organophosphorus insecticides against the rice bug when administered topically on the venter of the abdomen was next investigated. The procedure followed here was essentially the same as that adopted for the study of the action of gamma BHC against a series of strains of bugs collected from various localities. In this instance however bugs collected from the Kirindigala and Hindagala areas were used for the studies. Table 2 gives the results of these studies. The insecticide gamma BHC still has the highest toxicity rating of the six insecticides tested and the insecticdes may be arranged in the following descending order of toxicity to the pest on the basis of LD 50 data obtained :— gamma BHC→endrin→dieldrin→isodrin→malathion→diazinon.

POSSIBLE DETERIORATION OF QUALITY OF BHC PRODUCT USED AGAINST L. VARICORNIS

The bulk of the BHC dust used against *L. varicornis* during the past 9 years was one proprietary product. It seems possible that the poor control of the pest reported from the field was due to a deterioration in the quality of this formulation. Tests were therefore conducted to

TABLE 1—Susceptibility of a series of strains of L. varicornis *to the action of BHC*

Strain of Bugs	*LD 50 for BHC in μg*/bug*	*Standard Error in LD 50*	*Ratio of LD 50 to LD 50 of Aludeniya Strain*
Aludeniya ..	0·0209	0·00264	—
Galella ..	0·0209	0·00116	1·0
Kirindigala ..	0·0252	0·00116	1·2
Bathalagoda ..	0·0323	0·0015	1·5
Hindagala ..	0·0525	0·00513	2·5
Ulagalla ..	0·0563	0·0015	2·7
Puttalam ..	0·1390	0·00109	6·6

*1μg = 1 microgram or one millionth of a gram.

TABLE 2—Susceptibility of L. varicornis *to the action of a series of insecticides*

Insecticide	*LD 50 in μg/bug*	*Standard error of LD 50*	*Ratio of LD 50 to LD 50 for BHC*
BHC ..	0·0209	0·00264	—
ENDRIN ..	0·0296	0·00115	1·4
DIELDRIN ..	0·0502	0·00115	2·4
ISODRIN ..	0·0525	0·00111	2·5
MALATHION ..	0·111	0·00108	5·3
DIAZINON ..	0·191	0·00106	9·1

assess the gamma isomer content of BHC in the product by bioassay techniques. This was found to be up to the specified level. No tests were conducted on the physical properties of this dust but the results of field trials conducted with it to be reported below suggest that these properties were not below standard.

FIELD EXPERIMENTS ON THE CONTROL OF L. VARICORNIS WITH GAMMA BHC AND OTHER INSECTICIDES

In the field experiments to be reported below the test insecticides were applied both by dusting and by spraying techniques. For dusting the power-driven Mistral 2 Birchmeier duster was used, while for spraying the double-lanced knapsack sprayer was used (Fernando et al. 1954, Fernando 1956).

Field trials on the control of the paddy bug were carried out in rice tracts near Puttalam where the most resistant strain of bugs yet noted were found and near Anuradhapura where a relatively susceptible strain of bugs was to be found. In the first series of tests dusts were tried out using the light power duster and applying the dust at the rate of about 20 lbs. per acre. The dusts used were DDT 5 per cent, gamma BHC 0.65 per cent and 1.3 per cent, endrin 1.5 per cent, dieldrin 1 per cent, diazinon 1 per cent, and a mixture of diazinon 1 per cent and gamma BHC 0.65 per cent in equal parts. The treatments were randomized and duplicated, using about a $\frac{1}{4}$ acre extent rice tract as a single plot and allowing sufficient space between treatments to obviate the chances of the dusts from one plot affecting the results in the next plot. Dusting was conducted early in the morning, after population assessments had been made in each plot by five sweeps with hand nets at five spots randomly selected. Population assessments were repeated in a similar manner 24 hours after treatment for evaluation of the effectiveness of the insecticidal treatments used. Paddy in the Puttalam tracts were grown under poor soil and other cultural conditions. Consequently the crop was short and leaf growth poor and sparse. The Anuradhapura tracts on the other hand were cultivated under optimal conditions. Consequently the growth was concentrated and the leaves provided heavy cover for the pest. The results of the dusting trials are presented in Table 3.

The results presented in Table 3 show clearly a difference in the susceptibility of the Puttalam strain of bugs from that of the Anuradhapura strain to the entire series of chlorinated hydrocarbon insecticides used. This difference is more marked in the results obtained with DDT, endrin and dieldrin than those obtained with BHC although BHC has been the insecticide to which the bugs have

TABLE 3—Action of insecticidal dusts against two strains of paddy bug Leptocorisa varicornis

Insecticide dust and per cent Active Ingredient	*Bug populations before and 24 hours after treatment*				*Per cent Mortality of Bugs 24 hours after treatment*	
	ULAGALLA STRAIN		*PUTTALAM STRAIN*			
	Before Treatment	*24 hours after Treatment*	*Before Treatment*	*24 hours after Treatment*	*ULAGALLA STRAIN*	*PUTTALAM STRAIN*
DDT 5 per cent	59	8	91	29	77·5	68·1
ENDRIN 1·5 per cent	39	0	155	16	100	89·7
DIELDRIN 1 per cent	55	4	143	50	90·3	65·0
Gamma BHC 0·65 per cent	62	0	70	2	100	97·1
Gamma BHC 1·3 per cent	41	0	115	3	100	97·8
DIAZINON 1 per cent + Gamma BHC 0·65 per cent in ratio 1/1	73	2	52	4	95·8	92·3
DIAZINON 1 per cent	61	4	117	102	92·5	91·8

TABLE 4.—Action of insecticidal sprays against two strains of paddy bug Leptocorisa varicornis

Insecticide Formulation	Dilution in water	Bug Populations before and 24 hours after treatment				Per cent Mortality of Bugs 24 hours After treatment	
		UDAGALLA STRAIN		PUTTALAM STRAIN			
		Before Treatment	24 hours after Treatment	Before Treatment	24 hours after Treatment	UDAGALLA STRAIN	PUTTALAM STRAIN
DDT 25 per cent. E. C.	1 fl. oz. gal.	20	3	26	0	85·2	100
	4 fl. oz. gal.	40	7	18	1	77·9	96·2
DIELDRIN 20 per cent E. C.	1 fl. oz. gal.	74	10	48	0	86·5	100
	2 fl. oz. gal.	110	0	31	0	100	100
ENDRIN 20 per cent E. C.	1 fl. oz. gal.	55	2	23	0	96·7	100
	2 fl. oz./ gal.	30	1	57	0	96·4	100
Gamma BHC 20 per cent E. C.	1 fl. oz. gal.	105	0	8	0	100	100
	3 fl. oz. gal.	41	1	20	0	98·4	100
MALATHION 50 per cent. E. C.	4 cc./ gal.	53	4	31	2	92·7	93·5
	12 cc./ gal.	11	0	34	1	100	97·1
DIAZINON 60 per cent E. C.	2 cc./ gal.	46	24	41	0	35·9	100
	6 cc. gal.	46	11	20	1	74·9	95·0

been predominantly exposed to in the past. The results obtained with diazinon on the other hand are similar for both strains.

In the insecticidal trials using spraying techniques against the bugs in the same areas, viz., Puttalam and Anuradhapura, the spray was applied at the rate of about 60 gallons per acre by way of the double-lanced knapsack sprayer. Of the knapsack type of hand-operated sprayers, the double-lanced knapsack sprayer, with its adapted boom jets, had a swath width of over 12 feet (Fernando 1956) and therefore its use in maturing paddy tracts resulted in a minimum of damage by trampling of plants by the spray operators. Table 4 gives the results of the spray trials against the two strains of bugs.

It will be noted from Table 4 that the Puttalam strain is highly susceptible to the action of all the sprays whereas with the Anuradhapura strain the control achieved by the same sprays is somewhat less complete. As mentioned earlier the growth in the Anuradhapura test tracts was much more vigorous than that in the Puttalam tracts. Consequently with equal rates of application the results obtained are not contrary to what might be expected in view of the fact that the bugs in the Anuradhapura tracts were less accessible to the sprays.

DISCUSSION

Studies on the toxicity of gamma BHC to a series of strains of *L. varicornis* collected from various localities in the North-Western and Central Provinces have proved that a degree of resistance or tolerance to this insecticide has been developed by most of the strains. The extent of resistance developed would appear to be related both to the amount of exposure of bugs to BHC treatments in past years and in one case at least to other environmental factors.

The strains of bugs collected from Aludeniya and Galella can be regarded as representing that level of susceptibility of this bug to BHC which obtained when BHC was first used in this country. This conclusion is justified because both populations were relatively isolated and BHC treatments had never been applied either against them or against the pest in neighbouring areas for several miles around these areas. All the other five strains of *L. varicornis* studied had been exposed to BHC treatment for varying periods in the past years. At Kirindigala dusting with BHC had been done only during the past 2 to 3 years while at Batalagoda, Hindagala and Ulagalla dusting with BHC had been practised for the past 7 to 9 years. The situation with regard to the Puttalam strain that was studied was somewhat different. This strain, which showed the highest level of resistance to BHC, was securely isolated because the 15—20 acre tract in which they

were found was surrounded for at least 5 miles by high virgin forest. In the previous season the pest had multiplied into enormous proportions on an unevenly flowering crop and destroyed the crop completely while inadequate dusting had permitted survival of the pest in numbers. While a degree of resistance to gamma BHC ranging up to 2.7 fold that of normal strains has developed in strains of *L. varicornis* exposed to this insecticide in the past 6 to 8 years, the 6.6 fold normal level of resistance exhibited by the Puttalam strain of bugs is most likely the result of repeated exposure to sublethal dosages of gamma BHC coupled with ideal conditions for population build-up and in-breeding of bugs surviving gamma BHC treatments within this highly isolated tract.

The question of the extent to which the development of a degree of resistance to BHC by a number of strains of *L. varicornis* has affected the results of field control of this pest with BHC dusts has been studied. In these studies the most resistant Puttalam strain and slightly resistant Ulagalla strain were used for field-scale control tests. The results showed that while poorer control was achieved against the Puttalam strain with all the chlorinated hydrocarbon insecticidal dusts the difference noted in the results against two strains where gamma BHC dusts were used was very small and certainly did not justify the conclusion that gamma BHC dusts if applied correctly and at the proper dosage was ineffective even against the most resistant strain of rice bugs. The addition of the organophosphorus (diazinon) dust to the BHC dust only reduced its toxicity against this pest.

The tests with insecticidal sprays carried out with the same insecticides and at the same rate of application against the two strains of bugs gave results which proved that sprays were more effective than dusts in all cases except for BHC preparations where the dusts proved as effective as the sprays. The poorer control achieved against the Ulagalla strain of bugs can be attributed to the more vigorous growth and consequent heavier protection afforded in Ulagalla for the bugs from the sprays as compared to the Puttalam tract which had a very poor crop and therefore did not afford any protection to the Puttalam strain of bugs against the spray droplets.

Examination of the conditions obtaining in the field in regard to the control of the paddy bug has shown that there are still many localities where knowledge of insecticidal control practices have yet to reach the cultivator and that where these measures are practised they are inadequately performed. This latter factor appears to be the main cause for the poor control results achieved against the pest with BHC dusts. Dusting with gamma BHC has been proved to be still

highly effective against this pest in spite of a degree of resistance developed by the pest. Dusting is also the most economical method of control of the pest unless a sprayer of the type of the double-lanced knapsack sprayer is used to reduce damage to the crop by trampling by the spray operator. Dusting with a 1.3 per cent gamma BHC dust at the rate of 20 pounds per acre is therefore still recommended for the control of the pest.

SUMMARY

(1) Seven strains of *L. varicornis* from widely separated localities have been studied for resistance to gamma BHC. All strains that had been exposed to BHC showed a degree of resistance to BHC ranging up to 6.6 fold that of bugs which were never exposed to BHC.

(2) Strains of bugs exposed to BHC for the past 6—9 years had developed up to a 2.7 fold resistance to this substance. The strain with a 6.6 fold resistance was unique and environmental factors other than exposure to insecticide alone are attributed to the development of this level of resistance.

(3) Gamma BHC dusts were effective against both the most resistant bugs and to bugs of lower levels of resistance. Poorer control of the most resistant strain of bugs was however achieved with other chlorinated hydrocarbon dusts.

(4) The addition of diazinon dust to BHC dusts reduced the toxicity of the latter against all strains of the bug.

(5) Spraying was more effective than dusting against this bug in all cases of the chlorinated hydrocarbon and organophosphorus insecticides tested except in the case of gamma BHC where dusting was as effective as spraying.

(6) Incomplete implementation of the control recommendations against *L. varicornis* is responsible for the poor control results reported from the field.

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THE EFFECT OF FREQUENCY OF MILKING ON DAILY MILK PRODUCTION IN INDIAN DAIRY BREEDS

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THE SENSITIVITY of the switch-back or double-reversal design for research on dairy cattle is widely recognized. Basically, this design permits the comparison of two treatments, although change-over designs of the Latin-square or round-robin type may be used for the comparison of more than two treatments. The main advantage of these designs is that they permit the completely random allotment of the animals to the treatment sequences, because the design and the method of analysis automatically remove from experimental error the between-cow variation in production level and most of the variation in persistency. Thus, grouping or pairing of animals for similarity prior to allotment or for balancing cow differences across treatments becomes completely unnecessary. This is a very great advantage particularly in small herds of dairy cattle where pairing of cows is almost an impossibility.

DESIGN

For minimum experimental error with the switch-back design, it is important that the cows should have passed the lactation peak at the commencement of the experiment and no cows should have passed five months of gestation at the close of the experiment. Four Red Sindhi and eight Sahiwal cows at the Dry Zone Research Station, Maha Illuppallama, that satisfied these requirements, were allotted at random to two lots, A and B, of six cows each. Three of the cows were in their first lactation, three in the second, and the remaining six were in their third or later lactations. Supplementary concentrate feeding according to level of production was given to all cows included in the experiment.

Lots A and B were placed on the following treatment sequences :

Experiment period	*Treatment sequences*	
	Lot A	*Lot B*
1st to 27th day	2 × milking	3 × milking
28th to 54th day	3 × milking	2 × milking
55th to 81st day	2 × milking	3 × milking

Where milking was carried out twice daily, the hours of milking were 4 a.m. and 4 p.m. ; for 3 × milking the hours were 4 a.m., 12 noon and 8 p.m.

To eliminate any possible carry-over or residual effects, the performance of cows during only the last twenty days of each experimental period was used for the statistical analysis described below. It may be noted here that other designs and methods of analysis exist which permit the estimation of residual effects without deleting the performances from the earlier portions of the periods. In the present experiment, however, the residual effects, if any, were of no particular interest and were therefore not studied.

RESULTS

The data from the experiment are shown in Table 1.

TABLE 1—Milk Yield Data in Pints in the Switch-back Experiment to determine the Effects of 2 × and 3 × milking

Lot	*Cow No.*	*PERIOD*					
		1st to 7th day	*8th to 27th day*	*28th to 34th day*	*35th to 54th day*	*55th to 61st day*	*62nd to 81st day*
		(2 ×)	(2 ×)	(3 ×)	(3 ×)	(2 ×)	(2 ×)
A	AD 97	73	218	78	222	71	193
	AD 70*	60	168	59	175	60	188
	AD 145	63	176	66	184	55	153
	AD 122	75	221	75	206	64	179
	AD 38	79	229	83	224	68	175
	AD 156	59	168	65	181	52	148
		(3 ×)	(3 ×)	(2 ×)	(2 ×)	(3 ×)	(3 ×)
B	N 223	56	158	51	130	53	141
	AD 57	88	252	76	204	81	204
	AD 104	66	218	71	182	68	192
	E 69	76	242	83	223	76	196
	AD 126	67	200	72	188	70	174
	AD 96	80	259	81	231	89	231

* The milk yield of cow No. AD 70 was adversely affected from the 43rd to the 45th day of the experiment by the illness and subsequent death of her suckling calf. Her yield during these three days was therefore corrected on the basis of her yield on the day prior to the calf's illness.

Using only the data for the periods 8 to 27 days, 35 to 54 days and 62 to 81 days for the analysis, the error variance was found to be 514.73, while the sum of squares for the comparison of 2 × and 3 × milking was 8008.33.

Hence, F = 8008.33 514.73 = 15.56 which is a highly significant value for degrees of freedom 1 and 10.

The magnitude of the increase in yield from 2 × milking to 3 × milking may be readily computed from Table 1. It will be seen that the average daily yield per cow was 6.6 per cent higher when she was milked thrice daily as compared with 2 × milking.

DISCUSSION

Parr and Sen (1947) claimed that in Tharparker cows at Karnal, an increase in average daily yield of 47 per cent was obtained by four times milking and special handling. Unfortunately, in their experiment, the effects of 4 × milking and handling on the one hand, and of age on the other, had been confounded, and the methods used by these authors to separate out the two groups of effects were not quite satisfactory.

With European cows, increases in yield of the order of 20 to 25 per cent have been obtained from 3 × as compared with 2 × milking. Lush and Shrode (1950) suggests multiplying 3 × records by 0.80 when they are first lactations and by 0.833 when they are later ones for correcting them to the basis of twice-a-day milking. Their data also hinted the possibility that the difference between 2 × and 3 × milking is even larger than 4 : 5 at extremely young ages.

By comparison, the average difference in yield of 6.6 per cent between 2 × and 3 × milking obtained in the present experiment is of very small magnitude indeed. The level of milk production in Red Sindhi and Sahiwal cows, which was of the order of 9.8 pints per cow per day in this instance, is so much lower than in European animals that perhaps the effect of the extra milking in relieving pressure in the udder is negligible. The additional expenditure that would be incurred in switching over from 2 × to 3 × milking of these cows would not be adequately balanced by the increase in production to warrant the adoption of 3 × milking as routine farm practice.

SUMMARY

A statistically significant increase in milk yield was obtained in Red Sindhi and Sahiwal cows by increasing the frequency of milking from two to three times per day. The numerical magnitude of this increase

was found to be of the order of 6.6 per cent. From an economic point of view, this increase does not appear to warrant the adoption of 3 × milking as routine farm practice in herds of Indian dairy cattle.

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RESEARCH NOTES

Milk Recording Practices

An undesirable practice associated with milk recording in some tropical countries is that of making an allowance for the milk suckled by the calf when computing lactation yields. In several indigenous breeds, the cows are so accustomed to nursing their calves that they often fail to let down their milk if the calves are not allowed to suckle for some time at each milking. Various corrections ranging from the vaguest mental allowance to systematic additions to the lactation yield or average daily yield have been made in the past in allowing for the milk consumed by the calf during suckling. At the Sakrand farm of Tharparker cattle in India quoted by Joshi and Phillips (1953), the average milk production was 2,527 lb., and it was estimated that a further 1,000 lb. would have been produced but was consumed by the calf during suckling. In a herd of Boran cattle bred for milk production in Kenya, reported by Faulkner and Brown (1953), a daily calf allowance of 6 lb. of milk was added to the total weight of milk actually drawn. This resulted in the recorded lactation yields being nearly double the quantity of milk collected in the pail; the average daily yield and the average lactation yield were 12.5 lb. and 3,687 lb. respectively inclusive of calf allowance, as compared with corresponding values of 6.5 lb. and 1,918 lb. respectively when such calf allowance was not made. It is obvious that the inclusion of an arbitrary calf allowance, as practised in this herd, can be very misleading when comparing the performance of different herds and breeds of cattle. Bunge and Kamya (1951) attempted to assess the amount of milk consumed by calves at Entebbe, Uganda, by collecting data throughout a single lactation of three newly calved cows with calf at foot. They weighed the calves before and after feeding and estimated that the amount of milk consumed averaged 93 gallons per lactation. They concluded that, although further trials would have to be carried out, it would appear that an additive correction of 90 gallons should be made to the record of a cow with a calf at foot when her milk yield is compared with that of a cow whose calf is pail-fed. One cannot, however, place much reliance on these results as they are based on very scanty data. But they have been cited here to indicate the confusion

that would result if one breeder added 90 gallons to a cow's yield as calf allowance, while another added 177 gallons.

The usual method of milking cows when weaning of calves at birth is not practicable, is to allow the calf to suckle the dam prior to the commencement of milking, then hand milk as much as possible and afterwards allow the calf to complete the operation by suckling again. This procedure could be much modified if it is appreciated that the function of suckling calves during milking is to induce milk flow in their dams through stimulating the secretion of oxytocin from the pituitary. In fact, the duration of suckling could be so reduced as to limit the quantity of milk consumed by the calf to a few ounces at each milking. This would invclve using the calf purely to induce the let down of milk, removing the calf as soon as milk flow has commenced, hand milking as much as possible, and repeating the whole process once or twice over if necessary, until all the milk has been drawn. Calves reared under this system are pail-fed after their dams have been milked. This method eliminates the need for making calf allowances when computing lactation yields.

A practical demonstration of this method has now been concluded with Red Sindhi first calvers at the Livestock Farm, Polonnaruwa. In an experiment designed for the purpose, the calves of 106 heifers were weaned at birth while those of 39 others were allowed to suckle their dams as a means of inducing the let down of milk. The number suckling was less than the number weaned because management policy at this farm aims at producing a completely weaned population in due course of time. Special precautions were taken in an attempt to ensure that weaning, where practised, was done without letting the dam see its calf at birth. Of course, these precautions were not always practicable, which may account for some of the failures reported below. Regarding suckling calves, the quantity of milk consumed by them direct from their dams was reduced to the barest possible minimum by allowing them to suckle only at the commencement of each milking until milk flow was evident. The calves were then withdrawn and hand milking of the dams undertaken immediately. The amount of milk produced in 305 days in the first lactation averaged 219 gallons for dams whose calves were weaned as compared with 216 gallons for dams which had suckling calves

Sixteen per cent. of the animals whose calves were weaned failed to give yields higher than a hundred gallons ; in fact, some of them gave no milk at all. This was, however, not peculiar to the weaned group. Even among dams whose calves were permitted to suckle, 13 per cent. failures were recorded that let down less than 100 gallons

milk. Eliminating those that gave less than 100 gallons milk—the average of 305—day milk yields of the weaned and non-weaned groups of dams were then found to be 255 and 244 gallons respectively.

The effect of weaning and suckling on service period was also subject to some investigation. It was found that the calving intervals associated with the first lactation tended to be significantly longer in the non-weaned group than in the weaned group. But no hard and fast conclusions regarding length of service period can be drawn from this study, because data on the onset of first heat after calving in the two groups were not available. Moreover, the short calving intervals in the Sinhala breed where weaning has not been found practicable casts some doubt on any possible association between suckling and length of service period.

The present experiment may therefore be regarded as conclusive insofar as it demonstrates the possibility of obtaining accurate records of production performance where suckling is permitted, without recourse to making arbitary calf allowances. It also shows that the "holding back" or the refusal to let down milk which is encountered in the first lactations of many Zebu breeds does not necessarily seem to be associated with the weaning or the suckling of calves. That this phenomenon has in the past been commonly attributed to weaning, may probably be due to the fact that weaning, where practised, has often been improperly done.

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METEOROLOGICAL REPORT

SUMMARY FOR JULY-SEPTEMBER, 1957

MONSOON WEATHER prevailed generally during July too, the conditions being fairly active during the first five days of the month, when many daily falls over 3 inches were recorded at stations in the south-western hill-country. The weather was mainly dry during the period 13th to 22nd. From 22nd to 25th, on account of weak monsoon conditions, evening thunderstorms were experienced in the eastern and north-eastern parts and in the lee of the hills. The rainfall was heaviest on the south-western slopes of the hills, where a few stations recorded totals over 30 inches, the highest being 45.91 inches at Kenilworth Estate (Ginigathena). From this region the rainfall decreased rapidly towards the coast, the monthly totals at the coast stations being of the order of 5 inches only. Outside the south-west quarter the rainfall was chiefly below 2 inches. About 30 stations, mainly in the north-western parts, received no rain at all. The rainfall was above normal in the south-western hill-country and neighbourhood, excesses on the slopes of the hills exceeding 10 inches. Slight excesses also occurred in the lee of the hills and in the eastern and north-eastern parts. There were a few appreciable deficits, mainly in Deniyaya area.

Monsoon weather continued during August too, with moderate south-westerly winds over the Island and rainfall mainly confined to the south-western parts, where it was light and scattered on many days, but fairly widespread on the 22nd. On the 28th, the rainfall was both widespread and moderately heavy in the south-west, with several daily falls over 2 inches. Monsoon conditions weakened occasionally, when afternoon or evening thunderstorms were in evidence on the leeside. Rain of this type occurred in the north and north-west on the 1st and 2nd, and on the east side on the 16th, 25th and 26th. The monthly rainfall was greatest in the south-western hill-country, but there were no totals exceeding 20 inches. From this region the rainfall decreased gradually, the monthly totals outside the south-west quarter as well as along the west coast being mainly below 2 inches. About 75 stations, chiefly in the north-western parts, received no rain at all. The rainfall was below normal, practically throughout the Island, the greater deficits occurring in the south-western mid-country and

ranging from 5 to 10 inches. Deficits elsewhere in the south-west ranged from 2 to 5 inches. Small excesses occurred in places in the north and the east, where there were afternoon or evening thundershowers.

The weather was exceptionally dry again in September. The worst affected areas was the south-western hill-country and the adjacent mid-country, comprising the Watawala-Avissawella-Matugama-Ratnapura Districts, where stations which normally record over 20 inches of rain received less than half their average. As rainfall in August was also well below normal in these areas, the combined effect of the drought was very severe there, total deficits for the two months exceeding 20 inches at some stations. Thus, the amount recorded at Watawala was only 27.45 inches as against an average of 51.19 for the two months, while those at Kenilworth Estate (Ginigathena) and at Norton Bridge were 23.83 and 25.83 inches respectively, as against averages of 51.16 and a 50.56 inches. Such conditions were experienced in this area previous to this only in 1934—23 years ago. Apart from these Districts, there were other areas in the Island where acute drought conditions were experienced, because of deficient rainfall over several consecutive months. At these stations the actual monthly deficits were not excessive, but rainfall continued to be in short supply, month after month, during the past seven months. Places that suffered in this manner were Kalutara, Nakiadeniya, Deniyaya, Udapussellawa, Moneragala, Hambantota and Mullaittivu. Although the total deficit at Kalutara over the seven months was only 19.7 inches, it was a good 39 per cent of the average, while the deficit of 12.9 inches at Hambantota was as much as 65 per cent of the average. These conditions naturally resulted in grave hardship.

During September, on account of some north-westerly winds coming over from the Arabian Sea, the atmosphere was very dry and rainfall was generally light and confined to limited areas. The only period during which appreciable rainfall was experienced was from 28th to 30th, when there was fairly widespread rain in the interior, with several daily falls over an inch. The east side experienced rainfall in the form of evening thundershowers on the 8th and 9th. The bigger monthly totals ranged from 8 to 12 inches, and were found in the south-western foot-hills. Outside this area, as well as in the north-eastern hill-country and the neighbourhood of Trincomalee, rainfall ranged from 2 to 5 inches, while over the rest of the country it was below 2 inches. About 50 stations, chiefly in Puttalam and Hambantota Districts, recorded no rain at all. The raifall was below normal, almost

over the whole Island, larger deficits which occurred in the south-western hill-country and the neighbouring mid-country exceeding 10 inches. Deficits in North-Western Province and on the eastern slopes of the central hills ranged from 2 to 5 inches. Slight excesses, due to evening thundershowers, occurred scattered in the north-eastern parts and in the eastern mid-country.

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	JULY								
	Temperature				Humidity		Rainfall		
	Mean Maximum	Offset	Mean Minimum	Offset	Day	Night (from Min. Temps.)	Total	Offset	Number of Days
Anuradhapura ..	91·6	+0·7	76·0	+0·2	64	88	1·30	—0·02	4
Badulla ..	86·5	+0·3	64·5	+0·2	64	91	1·26	—0·91	8
Batticaloa ..	91·3	—0·6	77·3	+0·4	58	72	1·49	+0·45	5
Colombo ..	84·4	—0·3	76·5	—0·4	79	86	5·88	+0·39	17
Diyatalawa ..	78·8	+0·9	61·4	—1·1	64	84	0·96	—1·00	7
Galle	82·9	+0·2	76·4	—0·3	83	86	6·14	—0·20	17
Hambantota ..	89·0	+1·8	77·5	+1·2	69	84	0·59	—1·42	5
Jaffna	86·5	+0·4	80·3	+0·5	77	80	1·18	+0·63	4
Kandy	81·1	0	70·5	+0·7	72	82	9·11	+3·22	20
Kankesanturai ..	90·3	+0·4	70·7	+0·5	69	82	0·98	+0·44	3
Kurunegala ..	85·9	—0·4	75·9	+0·7	75	88	4·61	+0·73	18
Mannar ..	87·7	+0·3	79·8	+0·7	74	82	0·44	+0·09	2
Nuwara Eliya ..	66·2	+0·9	55·4	+0·5	82	88	10·02	—1·00	23
Puttalam ..	87·3	+1·2	79·2	+0·9	69	80	0·21	—0·78	1
Ratmalana ..	86·0	+1·4	78·3	+1·9	76	82	5·14	—0·10	14
Ratnapura ..	86·6	0	74·0	—0·4	74	93	13·84	+1·07	24
Talawakele ..	69·5	—0·7	59·9	—0·4	91	82	12·74	—0·56	24
Trincomalee ..	93·8	+1·4	78·7	+0·7	62	78	2·09	+0·36	5

	AUGUST								
	Temperature				Humidity		Rainfall		
	Mean Maximum	Offset	Mean Minimum	Offset	Day	Night (from Min. Temps.)	Total	Offset	Number of Days
Anuradhapura ..	92·2	+0·8	75·9	+0·4	59	86	0·03	—1·59	1
Badulla ..	87·5	+1·5	64·5	0	60	91	1·16	—2·04	8
Batticaloa ..	91·8	+1·4	76·8	+0·3	58	71	0·72	—1·23	5
Colombo ..	85·8	+0·9	76·7	—0·3	60	78	0·76	—2·36	4
Diyatalawa ..	78·4	+0·5	61·6	—0·1	80	86	5·24	—0·90	22
Galle	82·9	+0·3	76·5	—0·3	76	86	0·75	—0·69	5
Hambantota ..	88·0	+1·0	76·8	+0·6	79	85	1·76	+0·65	2
Jaffna	85·4	—0·6	79·5	+0·2	73	87	2·12	—2·62	18
Kandy	81·4	—0·8	70·1	+0·3	71	84	3·42	+2·16	5
Kankesanturai ..	89·6	—0·4	78·8	—0·2	69	86	1·08	—2·54	13
Kurunegala ..	87·6	+0·7	75·8	+0·9	76	84	0·03	—0·63	1
Mannar ..	86·7	—0·7	79·0	+0·3	81	85	5·16	—2·35	20
Nuwara Eliya ..	65·8	—0·3	55·2	+0·8	69	82	0	—0·65	0
Puttalam ..	87·7	+1·1	78·2	+0·3	74	84	1·45	—2·03	11
Ratmalana ..	86·1	+0·9	78·3	+0·9	71	88	7·28	—4·11	22
Ratnapura ..	84·3	—2·5	74·4	+0·2	—	89	7·21	—2·87	20
Talawakele ..	69·0	—2·0	59·4	+0·2	58	78	1·96	—1·65	1
Trincomalee ..	93·8	+1·7	78·4	+1·1	77	86	0·87	—3.16	8

	SEPTEMBER								
	Temperature				Humidity		Rainfall		
	Mean Maximum	Offset	Mean Minimum	Offset	Day	Night (from Min. Temps.)	Total	Offset	Number of Days
Anuradhapura ..	94·6	+2·8	75·6	+0·6	56	88	1·60	—2·15	3
Badulla ..	88·6	+3·0	64·0	—0·3	57	91	5·34	—0·15	7
Batticaloa ..	90·8	+1·1	76·4	+0·2	66	77	0·58	—1·81	4
Colombo ..	81·4	+3·6	60·6	—0·3	58	80	2·32	—2·09	7
Diyatalawa ..	82·6	—0·3	77·4	+0·6	82	84	0·86	—7·95	10
Galle	86·5	—0·1	76·9	+0·8	78	88	0·06	—2·70	1
Hambantota ..	85·8	—0·7	79·2	—0·1	77	82	1·50	—1·03	3
Jaffna	84·2	+2·0	67·7	+0·2	67	92	0·66	—5·32	8
Kandy	90·1	+0·3	78·8	—0·3	67	82	0·70	—2·27	3
Kankesanturai ..	90·6	+2·9	75·7	+1·4	61	84	0·63	—4·92	9
Kurunegala ..	86·7	—1·0	79·0	+0·2	75	84	0·26	—0·98	1
Mannar ..	68·9	+2·0	53·1	—0·1	75	82	2·17	—6·07	13
Nuwara Eliya ..	88·0	+1·0	78·4	+0·6	75	80	0·11	—1·47	1
Puttalam ..	86·7	+1·0	77·8	+1·4	71	82	0·35	—6·49	9
Ratmalana ..	88·9	+1·6	73·3	—0·2	66	88	2·71	—11·81	13
Ratnapura ..	71·8	—0·4	58·1	—0·2	79	88	3·86	—5·89	15
Talawakele ..	95·2	+3·1	77·9	+0·8	61	76	2·48	—0·95	6
Trincomalee ..	86·6	+1·2	76·4	—0·1	75	86	0·70	—6·14	6

IX INTERNATIONAL BOTANICAL CONGRESS
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THE Ninth International Botanical Congress will be held in Montreal, Canada, from August 19 to 29, 1959, at McGill University and the University of Montreal. The program will include papers and symposia related to all branches of pure and applied botany. A first circular giving information on program, accommodation, excursions, and other detail will be available early in 1958. This circular and subsequent circulars including application forms will be sent only to those who write to the Secretary-General asking to be placed on the Congress mailing list :

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